

AD-A178 333

BIOLOGY MANAGEMENT AND UTILIZATION OF COMMON REED

1/2

PHARAGMITES AUSTRALIS (U) URIVE UNIV AMSTERDAM

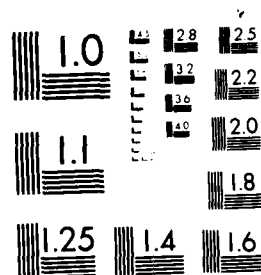
(NETHERLANDS) DEPT OF ECOLOGY AND ECOTOX...

UNCLASSIFIED

M U WERFF ET AL. FEB 87 DAJ445-86-A-0482

F/G 6/6

NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A178 333

BIOLOGY, MANAGEMENT AND UTILIZATION
OF COMMON REED

Phragmites australis

by

M. van der Werff, J.W. Simmers and S.H. Kay

DTIC FILE COPY

Vrije Universiteit
Department of Ecology and Ecotoxicology
P.O. Box 7161
1007 MC Amsterdam
The Netherlands

Waterways Experiment Station
Environmental Laboratory
P.O. Box 631
Vicksburg 39180
U.S.A.

This document has been approved
for public release and sale; its
distribution is unlimited.

BIOLOGY, MANAGEMENT AND UTILIZATION OF COMMON REED
Phragmites australis

Final technical report

by

Madelijn van der Werff
Vrije Universiteit
Department of Ecology and Ecotoxicology
Amsterdam

and

John W. Simmers and Stratford H. Kay
Waterways Experiment Station
Environmental Laboratory
Vicksburg

February 1987

United States Army
EUROPEAN RESEARCH OFFICE OF THE U.S. ARMY
London England

CONTRACT NUMBER DAJA45-86-M-0482

Approved for Public Release; distribution unlimited

© 1987
M. van der Werff, Schagen; J.W. Simmers and S.H. Kay, Vicksburg.

CONTENTS

1.	INTRODUCTION	1
1.1.	Background	1
1.2.	Objectives and scope	2
2.	GENERAL BIOLOGY	3
2.1.	Taxonomy and nomenclature	3
2.2.	Morphology	4
2.2.1.	Chromosomes	6
2.3.	Geographic distribution	7
2.4.	Physiological requirements	7
2.4.1.	Substrate	7
2.4.2.	Water level	9
2.4.3.	Temperature	10
2.4.4.	Light	11
2.4.5.	Evapotranspiration	12
2.4.6.	Nutrient uptake	13
2.4.6.1.	Nitrogen	14
2.4.6.2.	Phosphorus	17
2.4.6.3.	Potassium	21
2.4.6.4.	Sodium	23
2.4.6.5.	Chlorine	25
2.4.6.6.	Calcium	25
2.4.6.7.	Magnesium	28
2.4.6.8.	Iron and Manganese	31
2.4.6.9.	Other Micronutrients	32
2.5.	Ecology	34
2.5.1.	Plant communities	34
2.5.2.	Ecotypic variation	35
2.5.3.	Production	36
2.5.4.	Decomposition	41
2.5.5.	Succession	42
2.5.6.	Diseases	43
2.5.7.	Mechanical limitations	45
2.6.	Propagation	45
2.6.1.	Generative propagation	45
2.6.2.	Vegetative propagation	47

AI



3.	CONTAMINANT UPTAKE	49
3.1.	Heavy metals	49
3.2.	Organic contaminants	52
4.	UTILIZATION	54
4.1.	Use by wildlife	54
4.2.	Use by men	56
4.2.1.	Use on the stand	56
4.2.1.1.	Dewatering	56
4.2.1.2.	Bank protection	57
4.2.1.3.	Water purification	58
4.2.2.	Use after harvesting	62
4.2.2.1.	Energy source	62
4.2.2.2.	Industrial use	63
4.2.2.3.	Reed as building material	63
5.	MANAGEMENT	65
5.1.	Control	65
5.1.1.	Chemical control	65
5.1.2.	Mechanical control	65
5.2.	Management	66
5.2.1.	Grazing	66
5.2.2.	Burning	67
5.2.3.	Mowing and cutting	67
5.2.4.	Active regulation of the water table	68
5.3.	Nature conservation	68
5.4.	Reed cultivation	69
5.4.1.	Reed harvest	69
6.	REFERENCES	70
	APPENDIX A.	
	Bibliography non-referenced	86

Chapter 1

Introduction

1.1 Background

The common reed, *Phragmites australis* (Cav.) Trin. is a helophytic grass having a world-wide distribution. It generally inhabits wetlands, where under the proper conditions it may flourish and become the dominant plant species. Its survival and reproduction strategies make it also one of the first invaders in newly reclaimed wetlands as dredged material disposal sites or new-born polders. Despite its apparently aggressive growth, reeds do not normally invade healthy wetlands and displace other plant species. Reeds dominate a wetland only after a disturbance such as drainage or pollution. The common reed is able to withstand extremes of environmental conditions, including the presence of toxic contaminants. *Phragmites australis* is the dominant plant species on most Corps of Engineers (CE) dredged material disposal sites, particularly on the wetland-creation and confined upland disposal sites containing contaminated dredged materials.

Many of these sites have become prolific wildlife habitats, despite the presence of highly-contaminated dredged material placed within. Section 404 of the Clean Water Act, Public law 92-500, requires that environmental evaluations of dredged material discharge include the effects of disposal on "contaminant-concentration through biological processes". Therefore, the CE Districts have a crucial need to predict the bio-accumulation of contaminants in plants and animals that establish residence on wetland-creation and confined upland disposal sites containing contaminated dredged material before releasing the sites to State and local authorities for their use.

The cosmopolitan distribution, the ability to withstand extremes of environmental conditions, and the aggressive growth of *P. australis* make this plant a desirable species for vegetating new disposal sites containing contaminated dredged material.

1.2 Objectives and scope

The objectives of this report are to review and evaluate the literature pertaining to *Phragmites australis* with respect to its potential use in vegetating highly-contaminated dredged material and to provide CE Districts with guidelines for the establishment, maintenance and management of *P. australis* on dredged material disposal sites. Besides general biology emphasis will be placed upon:

1. Invasion into dredged material disposal sites
2. Contaminant uptake and translocation
3. Utilization
4. Management and control.



Photo 1. Dr. John W. Simmers in the middle of wealthy growing reeds, *Phragmites australis* at the dredged material confined disposal facility, Times Beach, Buffalo, N.Y. Courtesy Joop M. Marquenie.

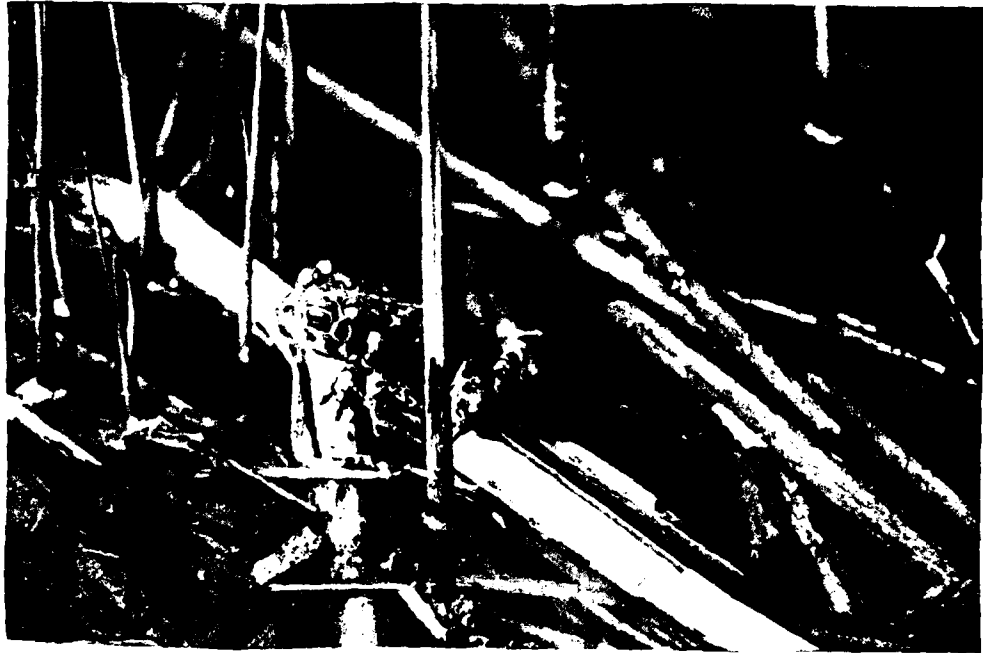


Photo 2. Reed lands used by amphibians for breeding. Times Beach, Buffalo N.Y., same location as photo 1, but now in early spring. Courtesy Joop M. Marquenie.

Chapter 2

General biology

2.1 Taxonomy and nomenclature

Clayton (1967) recognized three species of *Phragmites*: *P. communis* Trin., of both hemispheres; *P. karka* (Retz.) Trin. ex Steud., from Asia, Africa and Australia; and *P. mauritanus* from the tropics of Africa. Yim (1975) listed two additional species, with unspecified authors, *P. prostratus* and *P. longivalvis* from central Korea. Clayton (1968) suggested that the name *P. communis* Trin. is a synonym of *P. australis* (Cav.) Trin. ex Steud., erected in 1799, and that *P. australis* should take precedence. Haslam (1970b, 1972) recommended careful comparison of both European and Australian plants and that long-term transplant studies should be conducted before adoption of a new name, or establishment of *P. australis* as an additional valid species. However the U.S. National Herbarium has accepted *P. australis* as the proper name of this grass (personal communication, Dr. Thomas R. Soderstrom, Department of Botany, Smithsonian Institution, August 1977). The full synonymy of *P. australis* (Cav.) Trin. ex Steud. 1799 from Hitchcock (1950) and Clayton (1968) is listed below:

Arundo phragmites L. 1753
Arundo vulgaris Lam. 1778
Arundo palustris Salisb. 1796
Phragmites communis Trin. 1820
Reimaria diffusa Spreng. 1822
Cynodon phragmites Raspail 1825
Phragmites vulgaris Crep. 1866
Phragmites berlandieri Fourn. 1877
Phragmites phragmites Karst 1883
Trichoon phragmites Rendle 1899
Oxyanthe phragmites Nieuwl. 1914
Phragmites communis var. *berlandieri* Fern. 1925
Phragmites maximum var. *berlandieri* Moldenke 1936

2.2 Morphology

The following description of *Phragmites australis* is given after Hubbard (1968) (Fig. 1):

"A robust perennial, 1.5-3 m high, spreading by stout creeping rhizomes and stolons. Culms erect, rigid, stout, closely sheathed, many-noded, usually unbranched, smooth. Leaves greyish-green, smooth; sheaths rounded on the back, overlapping; ligule (LI,x2) a dense fringe of short hairs; blades contracted at the base, long-tapering to a very fine curved or flexuous tip, flat, 20-60 cm (or more) long, 10-30 mm wide, tough, closely nerved, ultimately falling from the sheaths. Panicles erect or finally nodding, 15-40 cm long, loose to dense, soft, purplish or brownish, much-branched, with smooth or nearly smooth branches, hairy at intervals; pedicels short. Spikelets (S,x3) lanceolate, at length widely gaping, 10-16 mm long, 2-6 flowered, with the lowest floret male and the others bisexual, the hairy axis breaking up at maturity beneath each fertile lemma (F). Glumes (G₁,G₂,x4) persistent, membranous, smooth, 3-5-nerved, the lower half to two-thirds the length of the upper, the upper about half the length of the lowest lemma. Lowest lemma (LL,x4) narrowly lanceolate, pointed 9-13 mm long, membranous, mostly 3-nerved, smooth. Fertile lemmas (F,L₁,x4) narrower, more finely pointed, thinner, 1-3-nerved, surrounded by white silky hairs (F) up to 9 mm long from the spikelet-axis. Paleas (P,x4) 3-4 mm long. Anthers (FL,x6) 1.5-2 mm long. Grain (CE,CH,x12) enclosed by the thin lemma and palea."

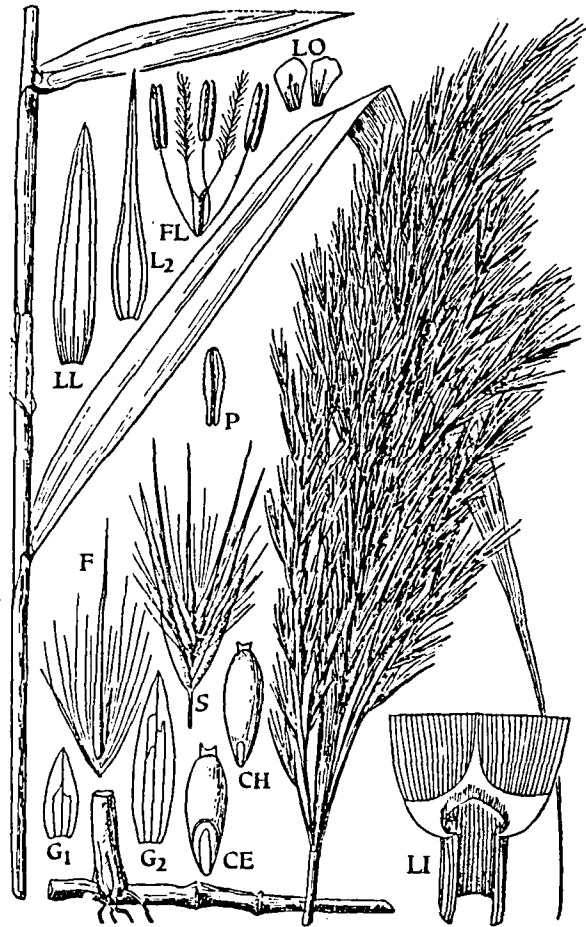


Fig. 1. *Phragmites australis*, after Hubbard 1968.
For explanation see text.

P. australis is a variable species (Haslam 1972, Van der Toorn 1972). Haslam (1972) has described the growth morphology in detail:

"Normally in a sparse stand a bud near the base of the last year's vertical rhizome develops, in late summer, into a horizontal rhizome growing in a similar direction to its predecessor. After extending for about 1 m, the rhizome apex turns upwards, and remains dormant near the surface until spring, when it grows into an aerial shoot, which may flower. The cycle is then repeated. Rhizomes normally live for 3-6 years. Any lateral bud can potentially develop into a horizontal or vertical rhizome, or an aerial stem."

The overwintering buds from the horizontal rhizomes are generally wider than those formed in spring and produce longer vertical rhizomes (Haslam 1969c). Horizontal rhizomes bear only one or two roots per node. Roots from upper parts of the vertical rhizomes will branch and form dense mats (Haslam 1972). The normal depth range for horizontal rhizomes is 0.4-1 m (Haslam 1972). Also depths down to 2 m are noted by Zonneveld (1959) and Hurliman (1951).

All aerial shoots are annual, except in frost-free regions where they may persist for 2 years. The tall robust shoots from wider buds are most inclined to flower. Smaller stems may bear small inflorescences, which emerge only if conditions are suitable (Haslam 1972). Inflorescences emerge in late July to early August in Britain; flowering occurs until late August or early September with the fruits maturing by November. Cross pollination takes place by wind. Seed dispersal is also normally by wind (Haslam 1972). In the United States and Canada, flowering generally occurs between July and September.

2.2.1 Chromosomes

The chromosome number of *P. australis* is generally accepted to be $2n=48$, where it concerns a tetraploid form (Van der Toorn 1972). Counts different from 48 in a karyological survey of 56 populations (Gorenflot et al. 1972) lie close to this value. Occasionally, hexaploid or octoploid clones are found (Björk 1967, Gorenflot et al. 1972). The relationships of various karyotypes of European varieties of *P. australis* have been described by Raicu et al. (1972).

2.3 Geographic distribution

Phragmites australis is found abundantly in temperate climates at low altitudes around the fringes of marshes, particularly upland of salt marshes and where salt marshes grade into freshwater wetlands. It has a circumpolar distribution. A map of the geographic distribution of *Phragmites australis* after Van der Toorn (1972) is given in Fig. 2. *P. australis* is found in all coastal states of the United States and has been reported to occur in nearly all states in the continental United States.

2.4 Physiological requirements

2.4.1 Substrate

Stands of *P. australis* are found in soil textures varying from gravel to silt and clay (Van der Toorn 1972, Boorman 1981). But they grow better in a fine texture (Haslam 1973). The organic content may vary from 1-97% (Misra 1938, Haslam 1972). They often occur in peat soils (Van der Toorn 1972, Boorman 1981). However, in some environments the contact with the soil is unnecessary, as the reed forms thick mats (0.5-1.2 m) floating on the water surface (Szczepanski 1978). *Phragmites australis* grows at a soil or water surface pH ranging from 3.6 to 8.6, but the more robust stands appear within a range of 5.5 to 7.5 (Haslam 1972). Various pH ranges reported in the literature are presented below (Table 1). *Phragmites* shows a clear preference for mesotrophic or eutrophic environments.

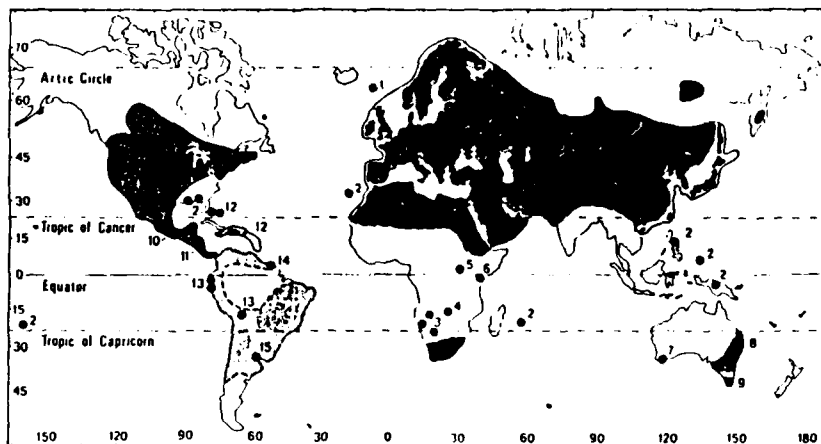


Fig. 2. Geographic distribution of *Phragmites australis*, after Van der Toorn 1972.

-  Distribution fairly well known; broken line indicates that the exact boundary of the distribution area is not known
-  Probably occurring; distribution not well known
-  Isolated finds

Numbers refer tot the following literature:

- | | |
|--------------------------------|-------------------------------|
| 1 OSTENFELD and GRÖNTVED, 1934 | 9 TOWNROW, 1969 |
| 2 HULTÉN, 1962 | 10 HITCHCOCK, 1913 |
| 3 LAUNERT, 1970 | 11 HITCHCOCK, 1930 |
| 4 GORDON-GRAY and WARD, 1971 | 12 HITCHCOCK, 1936 |
| 5 CONERT, 1961 | 13 HITCHCOCK, 1927 |
| 6 CLAYTON, 1970 | 14 ANSHOFF and HENRRARD, 1948 |
| 7 GARDNER, 1952 | 15 CABRERA, 1953 |
| 8 BURBRIDGE, 1966, 1968, 1970 | |

TABLE 1. pH Ranges reported in literature.

AREA	pH RANGE			REFERENCE
	Water	Soil	Unspecified	
Norfolk, England			7.2-7.3	Godwin and Turner (1933)
New Forest, England	5.0-5.4	4.9-5.3		Newbould and Gorham (1956)
Various English Lakes			5.3-7.3	Misra (1938)
Scotland			4.6-6.0	Gorham and Pearsall (1956a)
Kalenberg, The Netherlands		5.9-7.4		Van der Toorn (1972)
S. Sweden, several sites	5.3-8.0	4.5-9.3		Bjork (1967)
Western Utah			8.2-9.2	Bolen (1964)
Point Pelee, Ontario	6.8-7.5	6.9-8.1		Bayly and O'Neill (1972)

2.4.2 Water level

Phragmites usually grows with the water level, where the oxygen supply to the roots is low and so the redox potential is low. In order to overcome a long-term anaerobic condition *Phragmites* has an aerenchymatous system which can transport atmospheric oxygen to the roots. In temperate climates the plant can occur as much as 2 m above and about 1 m below the permanent water level (Haslam 1970c). In warmer climates, *P. australis* will occur at greater depths (In Uganda as deep as 4 m; Haslam 1972). In Britain, the maximum depth of approximately 1.5 is associated with mineral-rich water. Because few competitors exist in deep water, an insufficient oxygen influx (Yamasaki 1984) and nutrient status appear to control the lower boundary (Haslam 1970c, 1971b).

At the dry end of the range, *P. australis* usually occurs as a restricted population. Competition, nutrient status, and water level are controlling factors. Rhizomes can reach almost 2 m below the soil surface with roots penetrating even deeper, allowing the plant to reach low soil layers (Haslam 1970c). Water level effects bud width and consequently shoot height. Buds in unflooded soil tend to be high (slightly above and to 13 cm below the soil surface) and narrow, while those in flooded areas are wider and deeper (Haslam 1970c).

Under flooded conditions *P. australis* tends to have the highest production and the largest development of new rhizomes (Yamasaki 1981). This is in contradiction with the findings of Rezk and Edany (1979). They found tallest shoots at a water level of 0.1 m below soil surface. Shoot density was not considered. For effects of drainage and drying of the soil on an established dense reed vegetation, see "succession" and "management".

2.4.3 Temperature

Phragmites australis is found in temperate and warm climates. It is not found in arctic regions and on high altitudes. An increase in height of aerial shoots is noted with decreasing latitude and altitude as well as warm summers (Haslam 1972).

Young shoots grow fastest at approximately 25 °C (Haslam 1971c, 1973). Frosts or cold will increase shoot density, crop weight, and pre-emergence period (Haslam 1969b, 1972) and will stimulate bud development, but in turn will decrease stem height and

diameter. Severe frosts of -14 °C or below may kill up to 100 % of the shoots. Buds cannot survive more than three consecutive days of frozen soil (Haslam 1972). A high water level tends to protect new shoots from frost in cooler climates (Haslam 1970c). Haslam (1972) found recovery from frost damage may be very slow.

Haslam (1972) stated that a hot summer can increase reed height up to 0.5 m. The increased length occurs at the internodes. Generally, short-duration of hot and cold spells have little effect on the overall growth-rate (Haslam 1969b). Seedling establishment, bud emergence, and the timing of the growth cycle are the areas of possible temperature related ecotypic variation (Haslam 1975).

2.4.4 Light

The absence of light inhibits the seedling growth rate of *P.australis* (Haslam 1971c, 1972, 1973). Insufficient light will cause the development of flaccid leaves and an increase in blade weight. Biotopes normally producing a pronounced ribbing of the blades will not manifest this character (Haslam 1971c, 1972, 1973). Shading will tend to decrease the size of the stem and cause the inflorescence to be less dense (Lambert 1946). Shaded shoots tend to be narrower with longer blades (Haslam 1971c).

An evaluation of the effects of variation in the amount of shoot area exposed to light, amount of light available, and water depth on the rate of transpiration in *P.australis* was reported by Burian (1971, 1973). Among the environmental variants were temperature and seasonal fluctuations in the amount of radiant energy received. The correlation between the amount of radiant energy and apparent photosynthesis as indicated by the amount of CO_2 used per day varied according to temperature. Ondok (1973a)

2 developed a model of extinction of PhAR (photosynthetically active radiation) in a *Phragmites* stand. The model is based on the "relative volume of shading" (V_r) defined by the size of the plant aerial organs and their spatial distribution. In further considerations by Ondok (1973b), SLI (sunlit area index) and its daily course were correlated for four dates in the growing season, as was the distribution of irradiance by PhAR on the sunlit foliage area (E_l). SLI and distribution of E_l depend on changes in canopy shape and vary during the growing season. The sharp difference observed in E_l values between high and low sun elevation in spring and fall seems to be less favorable for photosynthetic activity than the more constant values of summer.

The photosynthesis of a single shoot of *P.australis* was examined by Walker and Waygood (1968). A plastic bag was fastened over a plant 1.64 m high with 15 internodes, 14 leaves and an unrolled terminal leaf. CO_2 was administered for one hour on a

2 clear day and subsequently extracted from the plant parts. The greatest concentration of CO_2 was found in the central leaves.

2 The leaf sheaths and internodes fixed only 8% of the total. Leaf area was the only index useful in determining photosynthesis, and

-2 -1 an average of 6.1 ± 0.62 (S.D.) mg CO_2 .cm⁻² .hr⁻¹ was

2 determined. The rate of photosynthesis increased from the lowest to the uppermost leaves, a finding supported by Dykxjova et al. (1970).

Oxygen content of rhizomes, stems, and leaves was studied by Krasovskii and Chashchukhin (1974). The oxygen content of the rhizomes in flooded ground, increased from 4-9 % in spring to 15-19 % in midsummer. Oxygen content of stems varied from 19-22 % and of leaves from 12-23 %. It was presumed that oxygen resulting from photosynthesis was transferred to the rhizomes.

2.4.5 Evapotranspiration

The transpiration rate for *P. australis* is considered high, varying with the ecotype of the plant and temperature. Transpiration occurs between May and September in Great Britain with peak periods in July and August (Haslam 1970c). In Manitoba, Canada, Phillips (1976) found the peak period of transpiration also occurred in July. Transpiration accounted for 75-90% of evapotranspiration, depending on the site. Gravimetric measurements of transpiration in *Phragmites* have been made by several Central European plant physiologists. A summary of results of daily values of evapotranspiration are presented below (Table 2).

TABLE 2. Daily values of evapotranspiration (in mm)

EVAPOTRANSPIRATION	CIRCUMSTANCES	REFERENCE
12.2	single leaves, July	Tuschl (1970)
13.7		
7.7-7.9	whole shoots, littoral stand	Kvet (1973b)
6.9-11.4	whole shoots, limnosal stand	Rychnovska and Smid (1973)
5.6	vigorously growing, 1 June	Smid (1975)
6.9	id. 27 June	id.
5.5	id. 11 August	id.
1.4	id. 5 October	id.

Evapotranspiration of vigorous *P. australis* stands was considered by Vostkova (1975) to remove a large amount of subsurface water and effect the hydrological condition of the sand deserts of the Northern Aral region of the U.S.S.R. In the Netherlands (Van der Toorn 1982) and Japan (Kamio 1982), *Phragmites* is often introduced in polders after initial reclamation. The active transpiration of *P. australis* plants can reduce soil water in the lower layers of the ground and so help to reduce water the content of muddy soil.

Khashes and Bobro (1971) found daily transpiration characterized by a single peak at 12.00 - 13.00 h. They suggested that the morning transpiration value is correlated with air temperature and deficit of saturation while the afternoon drop in transpiration is conditioned by the physiological state of the leaves.

Additional factors regulate the evapotranspiration rate. Krolikowska (1971) examined *Phragmites* at terrestrial and aquatic sites around Midolajski Lake, Poland, and found evapotranspiration increases in proportion to increases in fresh weight, air temperature, and solar radiation. As expected a rise in relative humidity decreased transpiration, as did inflorescence formation. The intensity of transpiration rose rapidly in the morning and decreased in the afternoon. The younger leaves of the upper portion of the aerial shoots transpired more than the lower (older) leaves. Pazourek (1973) found a stomatal gradient did exist from basal to apical leaves.

2.4.6 Nutrient uptake

As mentioned above, *Phragmites australis* can grow in an exceptionally wide range of soil and water chemistry. It can be limited by different nutrients, depending on the nutrient status of the area concerned. *Phragmites* grows potentially well in mesotrophic and eutrophic habitats. As the nutrient concentration is usually higher in fine-grained substrates than in coarse-grained, *Phragmites* grows better in the former one. In eutrophic habitats *Phragmites* is frequently limited by competition (Haslam 1973). Haslam (1973) learned that nutrient uptake is mainly from the upper 0.5 m of the soil, by the branched horizontal roots of the upper rhizomes. But, the hydropotes of the submerged above-ground part of the aerial shoot may also play a large role in nutrient uptake, even many times higher than the uptake by the underground roots (Luther 1983).

A large number of measurements have been carried out on the nutrient status of soil and water in *Phragmites* stands and on the nutrient concentration in the plant tissue. In order to get an impression of the substrate characteristics of *Phragmites*, in this review a summary will be given of these data in natural stands. Also the effect of fertilizers will be mentioned and the effect of the season.

2.4.6.1 Nitrogen

Nitrogen (N) is absorbed by plant roots in the form of nitrate or ammonium ions.

Banoub(1975) measured the differences in water chemistry in the Gnadensee without and within a *Phragmites* stand. The pH decreases during the growing season as one penetrates deeper into the reeds as does the concentration of total inorganic N, of NO₂⁻-N and especially of NO₃⁻-N, whereas the NH₄⁺-N concentration increases. Table 3 gives the concentrations of different forms of N in the surface water in a reed stand. Table 4 gives the N concentration in the soil.

-1
TABLE 3. N concentration (in ug.l⁻¹) in the surface water
in a *Phragmites* stand.

	MINIMUM	MAXIMUM	AVERAGE	REFERENCE
NO ₂ ⁻ -N	1.0	69.0	7.8	(a)
	traces	23		(b)
NO ₃ ⁻ -N	40.0	250.0	131.3	(a)
	90	621		(b)
			420	(c)
	25	4990		(d)
	73	1126		(d)
NH ₄ ⁺ -N	91.0	450.0	177.0	(a)
	15	77		(b)
			540	(c)
	350	1500		(d)
	397	793		(d)
inorg-N	249.0	531.0	321.0	(a)
N total	10	3620		(d)

ref.a: Banoub 1975; ref.b: Kaul 1984 (8 sites, during 2 years;
ref.c: Ulehlova et al. 1973 (aver. over 1 year, 5 sites;
recalculated); ref.d: Dykyjova and Kvet 1978.

TABLE 4. N concentration (in mg.kg⁻¹ dry weight) in soil, sediment and sapropel in a *Phragmites* stand.

	SOIL	SAPROPEL	REFERENCE
NO ⁻ N 3	3.4	9.0	(c)
(NO + NO ⁻) - N 3 2	16 - 181 0.1 - 5.1	12 - 17	(h) (e)
NH ⁻ N 4	36	69	(c)
	26 - 605 51 - 238	30 - 73	(e) (h)
inorg.N (extractable)	3.3 - 39.6		(f)
total N	1800 - 5300 100 - 23800 5040 - 27200		(e) (f) (b)
(in g.l ⁻¹)	1.36 - 2.1		(g)

ref.b: kaul 1984 (during 2 years, 8 sites); ref.c: Ulehlova et al. 1973 (aver. over 2 years, 5 sites); ref.e: Boorman and Fuller 1981; ref.f: Ho 1981b; ref.g: Schlott and Malicky 1984; ref.h: Dykyjova and Kvet 1978 (sapropel: 0-25 cm, sediment 25-40 cm).

The variation of nitrogen concentration in water is a seasonal effect, whereas the variation in soil or sapropel is more a spatial one (Dykyjova and Kvet 1978). Dykyjova (1979) compared the N concentration in the soil with that of the plant (Table 5).

TABLE 5. N concentration in soil and plant tissue in mg.kg⁻¹ dry weight.

	SOIL	PLANT	CONCENTR. FACTOR
sand	0.7	1.53	2.18
deep layer of sapropel	1.7	1.91	1.12

Table 6 gives a survey of several values of N concentrations in

different organs of *Phragmites*.

TABLE 6. Range of N concentrations in tissues of *Phragmites australis* in % dry weight.

ORGAN		REFERENCE
rhizomes	0.689 - 1.417	(f)
	0.55 (0.59)	(m)
	1.06 - 1.53	(n)
	0.919	(c)
roots	0.968 - 1.85	(f)
	0.85 (0.86)	(m)
	0.992	(c)
root hairs	1.23 (1.09)	(m)
belowground organs	1.17	(q)
stems	0.939 - 1.601	(f)
	1.12 - 2.34	(i+j)
	0.83 (0.74)	(m)
	1.18 - 2.93	(n)
	0.12 - 0.53	(r)
	0.992	(c)
young		(c)
ripe	0.808	(c)
dying off	0.772	(c)
leaves	2.477 - 3.473	(f)
	1.3 - 2.7	(k)
	3.13 (2.42)	(m)
	3.35 - 5.10	(i+j)
	2.59 - 3.43	(r)
	4.41	(c)
young		(c)
ripe	3.16	(c)
dying off	3.013	(c)
stems+leaves	2.1 - 3.35	(e)
	1.233	(l)
	0.64 - 2.61	(g)
	0.79 - 2.88	(o)
	1.11 - 1.96	(p)
	1.36	(q)
panicle	1.00 - 2.77	(j)
	1.938 - 3.420	(f)

ref.c: Ulehlova et al. 1973; ref.e: Boorman and Fuller 1981;
 ref.f: Ho 1981b; ref.g: Schlott and Malicky 1984; ref.i: Kvet
 1973; ref.j: Dykyjova 1979; ref.k: Allen and Pearsall 1963;
 ref.l: Auclair 1979; ref.m: Kovacs et al. 1978 (the data between

brackets are from 1 year later) ref.n: Van der Linden 1980 (variation over 1 year); ref.o: Best 1981 (variation over 1 year); ref.p: Van der Toorn 1972 (min. and max. of 29 sites in August); ref.q: Roman and Daiber 1984 (mean annual value of 8 and 15 samples resp); ref.r: Sieghardt and Maier 1985 (min. and max. of season)

The N concentration in plant tissue is highest in the growing season. The % N decreases in leaves and stem from 2.61 in June to 0.64 in January (Schlott and Malicky 1984) and from 2.77 in May to 1.00 in October (Dykyjova 1979). The N content of the shoots decreases after August, whereas the N content of the rhizomes increases. This shows the internal retranslocation of N in the plant. Also the appearance of the new shoot biomass in the first half of the growing season coincides with a decrease of the N content of the rhizomes (Van der Linden 1980). In relation to this the N concentration decreases with age (Ulehlova et al. 1973).

Allen and Pearsall (1963) found that shoot production is related with the quota of N per leaf (Allen and Pearsall 1963).

2.4.6.2 Phosphorus

Another important macronutrient is phosphorus (P). Table 7 gives some data of the phosphate concentration of the surface water in a reed stand. The concentration of P in water can fluctuate heavily during the season (Bayly and O'Neill 1972). Like in nitrogen Banoub (1975) also found higher P concentrations inside the reed stand than outside.

Table 8. gives some data about the P status in the soil of a reed stand. The data of the soil extract or available P can differ according to the extraction method used.

-1

TABLE 7. Range of concentration of P (in mg.l⁻¹) in the surface water in a reed stand.

				REFERENCE
TP	0.15	-	0.79	(a)
	0.159	-	0.552	(b)
	0.87			(d)
	0.02	-	1.0	(e)
	0.024	-	0.240	(c)
DIP	0.029	-	0.046	(b)
	0.003	-	0.084	(c)
DOP	0.124	-	0.518	(b)
	0.010	-	0.084	(c)
PIP	0.001	-	0.010	(c)
PDP	0.011	-	0.072	(c)

TP (total phosphate-phosphorus); DIP (dissolved inorganic phosphate-phosphorus); DOP (dissolved organic phosphate-phosphorus); PIP (particulate inorganic phosphate-phosphorus); PDP (particulate organic phosphate-phosphorus)

ref.a: Bayly and O'Neill 1972 (min and max. during the season);
 ref.b: Kaul 1984 (8 sites, during 2 years); ref.c: Banoub 1975;
 ref.d: Ulehlova et al. 1973; ref.e: Ho 1981 (min and max. of 3 sites).

-1

TABLE 8. Range of concentrations of P in soil in a reed stand in mg.kg⁻¹ dry weight.

TOTAL P	SOIL EXTRACT/ AVAILABLE P	sapropel EXTRACT	REFERENCE
240 - 800			(a)
540 - 2320	20 - 130		(b)
	8.2	11.7	(d)
	51 - 380		(f)
	0.3 - 33.1		(e)

ref.a: Bayly and O'Neill 1972 (min. and max. during the season);
 ref.b: Kaul 1984 (8 sites, during 2 years; ref.d: Ulehlova et al. 1973 (mean value of 5 sites over 2 years, monthly); ref.e: Ho 1981 (min. and max. of 4 sites); ref.f: Boorman and Fuller 1981 (min. and max. of 6 sites).

Bayly and O'Neill (1972) found an increase in the total P concentration in the soil from May to August.

The concentrations of P in different organs of *Phragmites* is summarized in Table 9.

TABLE 9. Range of concentrations of P in *Phragmites australis* in % dry weight.

ORGAN		REFERENCE
rhizome	0.06 (0.08)	(h)
	0.406	(d)
	0.133 - 0.238	(e)
root	0.09 (0.10)	(h)
	0.309	(d)
	0.171 - 0.541	(e)
root hair	0.10 (0.14)	(h)
stem	0.07 (0.08)	(h)
	0.084 - 0.185	(i + j)
	0.164 - 0.237	(e)
	0.04 - 0.13	(p)
young plants	0.293	(d)
ripe plants	0.172	(d)
dying off plants	0.180	(d)
leaves	0.13 (0.15)	(h)
	0.152 - 0.240	(i)
	0.03 - 0.17	(j)
	0.21 - 0.38	(e)
	0.14 - 0.22	(p)
	0.353	(d)
young plants	0.309	(d)
ripe plants	0.231	(d)
dying off plants	0.125 - 0.240	(i)
stem + leaves	0.15 - 0.79	(a)
	0.1515	(q)
	0.245 - 0.415	(f)
	0.033 - 0.312	(k)
	0.17 - 0.48	(l)
	0.20 - 0.36	(m)
	0.029 - 0.149 (mean: 1.05 ± 0.26)	(n)
nutrient poor	0.071 - 0.194	(o)
	0.19	(l)
nutrient rich	0.28	(l)
panicle	0.299 - 0.496	(e)

ref.a: Bayly and O'Neill 1972; ref.b: Kaul 1984 (8 sites, during 2 years; ref.d: Ulehlova et al. 1973; ref.e: Ho 1981 (min. and max. of 3 sites); ref.f: Boorman and Fuller 1981 (min. and max. values of 6 sites); ref.g: Auciair 1979; ref.h: Kovacs et al. 1978 (values between brackets are from 1 year later); ref.i: Kvet 1973a (min. and max. values of 14 sites); ref.j: Allen and Pearsall 1963 (min. and max. values of 11 sites); ref.k: Schlott and Malicky 1984; ref.l: Dykyjova 1979 (min and max of 14 sites at the peak of the growing season; the poor soil represents a sandy soil, the rich soil a deep layer of sapropel); ref.m: Best et al. 1981; ref.n: Kufel and Kufel 1980 (min., max. and mean of 37 sites); ref.o: Van der Toorn 1972 (min. and max. of 29 sites in August); ref.p: Sieghardt and Maier 1985 (min. and max. of season).

Bayly and O'Neill (1972), Dykyjova (1979), Best et al. (1981) and Schlott and Malicky (1984), found the highest P levels in the shoots in spring, which decrease to the low levels in autumn and winter.

2.4.6.3 Potassium

Potassium (K) levels in the surface water and soil in a reed stand are given in Table 10 and Table 11.

-1

TABLE 10. Range of K levels (in mg.l⁻¹) in the surface water in a reed stand.

	REFERENCE
5.6 - 13.0	(a)
0.71 - 2.52	(b)
0.2 - 10	(c)
30.33	(d)
1.21 - 7.89	(e)

ref.a: Bayly and O'Neill 1972; ref.b: Kaul 1984 (8 sites, during 2 years); ref.c: Allen and Pearsall 1963 (min. and max. of 11 sites); ref.d: Ulehlova et al. 1973 (5 sites, during 2 years); ref.e: Ho 1981b (min. and max. of 3 sites).

Bayly and O'Neill (1972) found an increase in the K concentration from May to August.

-1

TABLE 11. The range of K concentrations (in mg.kg⁻¹) in the soil in a *Phragmites* stand.

	TOTAL K	EXTRACT (1N ammonium acetate)	REFERENCE
		50 - 280	(a)
	4800 - 21200		(b)
bottom	224		(d)
sapropel	335		(d)
		19.7 - 570	(e)

ref.a: Bayly and O'Neill 1972 (variation during the year); ref.b: Kaul 1984 (8 sites, during 2 years); ref.d: Ulehlova et al. 1973 (5 sites during 2 years); ref.e: Ho 1981 (min. and max. values of 4 sites).

TABLE 12. Range of K concentrations in different organs of *Phragmites australis* in % dry weight.

ORGAN		REFERENCE
rhizome	0.95 (1.24)	(q)
	0.709	(d)
	1.325 - 1.878	(e)
root	0.459	(d)
	0.64 (0.63)	(q)
	0.570 - 0.842	(e)
roothair	0.44 (0.95)	(q)
stem	0.89 (1.16)	(q)
	0.55 - 1.39	(h)
	1.821 - 2.223	(e)
	0.61 - 1.49	(j)
	0.24 - 0.92	(i)
young plants	1.123	(d)
ripe plants	0.509	(d)
dying off plants	0.325	(d)
leaves	1.13 (1.22)	(q)
	1.21 - 2.07	(h)
	0.07 - 0.85	(c)
	1.363 - 1.720	(e)
	1.21 - 2.07	(j)
young plants	0.85 - 2.14	(i)
ripe plants	1.060	(d)
dying off plants	0.840	(d)
dying off plants	0.499	(d)
stem + leaves	0.01 - 1.95	(a)
	1.392	(f)
	2.0 - 3.25	(i)
	0.55 - 2.76	(j)
poor soil	0.373 - 1.653	(k)
rich soil	1.08	(j)
rich soil	1.74	(j)
panicle	1.247 - 1.740	(e)

ref.a: Bayly and O'Neill 1972; ref.b: Kaul 1984; ref.c: Allen and Pearsall 1963 (min. and max. of 11 sites); ref.d: Ulehlova et al. 1973; ref.e: Ho 1981b (min. and max. of 3 sites); ref.f: Auclair 1979; ref.g: Kovacs et al. 1978 (the data between brackets are from 1 year later); ref.h: Kvet 1973a (min. and max. of 14 sites); ref.i: Boorman and Fuller 1981 (min. and max. of 6 sites); ref.j: Dykxjova 1979 (min. and max. of 14 sites at the peak of the growing season; the poor soil represents a sandy soil, the rich soil a deep layer of sapropel); ref.k: Van

der Toorn 1972 (min. and max. of 29 sites in August). ref.1: Sieghardt and Maier 1985 (min. and max. of season).

Bayly and O'Neill (1972) and Dykyjova (1979) measured a decrease from a high K content in May to a very low K concentration in October.

2.4.6.4 Sodium

As *Phragmites* occurs on inland sites as well as on the upper edges of salt marshes, there will be a large variation in the sodium (Na) concentration of the soil and surface water. Table 13 and 14 give the ranges of the substrate characteristics for Na in which *Phragmites* grows.

TABLE 13. Ranges of the concentration of Na (in mg.l⁻¹) in the surface water in *Phragmites* stands.

	REFERENCE
3.3 - 7.9	(a)
8 - 15	(b)
66.7	(c)
5.90 - 38.64	(d)

ref.a: Bayly and O'Neill 1972 (during the season); ref.b: Kaul 1984; ref.c: Ulehlova et al. 1973 (mean value of 5 sites during 2 years) ref.d: Ho 1981 (min. and max. of 3 sites).

TABLE 14. Range of concentrations of Na in the soil (in mg.kg⁻¹ dry weight) in *Phragmites* stands.

	TOTAL Na	EXTRACT (1N ammonium acetate)	REFERENCE
	420 - 1460		(b)
		43.0 - 438.9	(d)
bottom soil	95		(c)
sapropel	159		(c)

ref.b: kaul 1984; ref.c: Ulehlova et al. 1973 (mean value of 5 sites during 2 years); ref.d: Ho 1981 (min. and max. of 4 sites).

Table 15 gives the Na concentration in the different organs of *Phragmites*.

TABLE 15. Ranges of Na concentration in *Phragmites australis* tissue in % dry weight.

ORGANS		REFERENCE
rhizome	0.08 (0.11)	(e)
	0.184	(c)
	0.123 - 0.198	(d)
root	0.19 (0.24)	(e)
	0.206	(c)
	0.245 - 0.354	(d)
roothair	0.14 (0.32)	(e)
stems	0.05 (0.06)	(e)
	0.045 - 0.130	(f)
	0.082 - 0.105	(d)
	0.044 - 0.129	(g)
young plants	0.044	(c)
ripe plants	0.041	(c)
dying off plants	0.063	(c)
leaves	0.02 (0.04)	(e)
	0.035 - 0.08	(f)
	0.08 - 0.65	(h)
	0.032 - 0.049	(d)
young plants	0.035 - 0.080	(g)
	0.031	(c)
	0.031	(c)
	0.027	(c)
stems + leaves	0.02 - 0.052	(a)
	0.071	(i)
poor soil	0.056 - 0.270	(j)
	0.03	(g)
	0.05	(g)
panicle	0.056 - 0.089	(d)

ref.a: Bayly and O'Neill 1972 (fluctuations throughout the growing season); ref.b: Kaul 1984; ref.c: Ulehlova et al. 1973; ref.d: Ho 1981 (min. and max. of 3 sites); ref.e: Kovacs et al. 1978 (data between brackets are from 1 year later); ref.f: Kvet 1973a (min. and max. of 14 sites); ref.g: Dykyjova 1979 (min. and max. of 14 sites at the peak of the growing season); ref.h: Allen and Pearsall 1963 (min. and max. of 11 sites); ref.i: Auclair 1979; ref.j: Van der Toorn 1972 (min. and max. of 29

sites in August).

In a peat water regime, Daniels (1975) found a good correlation between the quantity of sodium in the water and that in the aerial portion of the plant. Such a correlation was not observed with other ions in the water.

2.4.6.5 Chlorine

There are only a few data on the chlorine (Cl) concentrations in the habitat of *Phragmites*. In a fresh water habitat Banoub (1975) measured a same Cl concentration in the water of 3.1 - 9.3

⁻¹
mg.l within as well as without the reed stand. Kaul (1984)

⁻¹
found a level in the water of 9 - 12 mg.l. However, the species shows a rather high salt tolerance. Ranwell et al. (1964) reported that *Phragmites* can tolerate up to 1.2 % chlorinity in the 10-12 cm soil layer. Juvenile plants seem to

⁻¹
be more sensitive, having a critical limit at 0.9 mg Cl.l, whereas adult plants show no inhibition at this concentration (Bakker et al. 1957). Haslam (1971c) discovered that plants of 10 cm high transplanted to a 2 % chloride value remained small. At a 1 % concentration, the transplants varied from small to the size of the controls. At a 0.5 % value, plants achieved a size comparable to controls. Presumably the controls were grown in fresh water.

Van der Toorn (1972) found 0.395 - 1.230 % Cl (dry weight) in the shoots of *Phragmites australis* as the range over 29 sites in August.

2.4.6.6 Calcium

The levels of calcium (Ca) concentration in the surface water (Table 16) in a reed stand can vary largely as also the pH range can be very wide.

TABLE 16. Range of Ca concentrations in the surface water in
-1
a stand of *Phragmites* in mg.l .

	REFERENCE
45 - 72	(a)
29 - 62	(b)
43.0 - 75.0 (av. 53.3)	(c)
3 - 270	(d)
91.37	(e)
5.77 - 31.82	(f)

ref.a: Bayly and O'Neill 1972 (during the season); ref.b: Kaul 1984 (min. and max. of 8 sites during 2 years); ref.c: Banoub 1975; ref.d: Allen and Pearsall 1963 (min. and max. of 11 sites); ref.e: Ulehlova et al. 1973 (mean value of 5 sites, during 2 years); ref.f: Ho 1981 (min. and max. of 3 sites).

Bayly and O'Neill (1972) didn't find a trend in the Ca concentration during the growing season. Banoub (1975) measured a slightly lower Ca concentration (aver. 49.3 mg/l) out of the reed stand.

TABLE 17. Range of Ca concentrations in the soil in a stand of
-1
Phragmites in mg.kg dry weight.

	TOTAL Ca	EXTRACT (1N ammonium acetate)	REFERENCE
	9600 - 18900		(a)
	19500 - 39500		(b)
bottom soil	2820		(e)
sapropel	3820		(e)
		66000 - 429000	(g)
	462 - 5015		(f)

ref.a: Bayly and O'Neill 1972 (during the season); ref.b: Kaul 1984; ref.e: Ulehlova et al. 1973 (mean value of 5 sites, during 2 years); ref.g: Boorman and Fuller 1981 (min. and max. of 6 sites); ref.f: Ho 1981 (min. and max. of 4 sites).

Ca concentrations, the total as well as in the extract, can vary enormously. No trends were found during the season (Bayly

and O'Neill 1972).

Ranges of Ca concentration as found in the tissues of *Phragmites* are presented in Table 18.

TABLE 18. Ranges of Ca concentrations in different organs of *Phragmites australis* in % dry weight.

ORGAN		REFERENCE
rhizomes	0.17 (0.35)	(h)
	0.386	(e)
	0.320 - 0.454	(f)
roots	0.75 (1.34)	(h)
	0.104	(e)
	0.252 - 0.468	(f)
roothair	1.39 (2.05)	(h)
stem	0.09 (0.08)	(h)
	0.062 - 0.129	(i)
	0.427 - 0.514	(f)
	0.062 - 0.156	(j)
	0.03 0.05	(n)
young plants	0.076	(e)
ripe plants	0.044	(e)
dying off plants	0.061	(e)
leaves	0.22 (0.19)	(h)
	0.245 - 0.651	(i)
	0.24 - 0.77	(d)
	0.692 - 0.973	(f)
	0.249 - 0.651	(j)
	0.16 - 0.58	(n)
young plants	0.190	(e)
ripe plants	0.319	(e)
dying off plants	0.376	(e)
stem + leaves	0.54 - 1.60	(a)
	0.278	(k)
	0.267 - 0.495	(q)
	0.14 - 0.29	(j)
	0.010 - 0.162 (mean: 0.064 ± 0.039)	(l)
poor soil	0.128 - 0.298	(m)
rich soil	0.03	(j)
rich soil	0.29	(j)
panicle	0.420 - 0.470	(f)

ref.a: Bayly and O'Neill 1972; ref.d: Allen and Pearsall 1963 (min. and max. of 11 sites); ref.e: Ulehlova et al. 1973; ref.f: Ho 1981 (min. and max. of 3 sites); ref.g: Boorman and Fuller 1981 (min. and max. of 6 sites); ref.h: Kovacs et al.

1978 (the data between brackets are of 1 year later); ref.i: Kvet 1973a (min. and max. of 14 sites); ref.j: Dykyjova 1979 (min. and max. of 14 sites at the peak of the growing season; the poor soil represents a sandy soil, the rich soil a deep layer of sapropel); ref.k: Auclair 1979; ref.l: Kufel and Kufel 1980 (min., max. and mean value of 37 sites); ref.m: Van der Toorn 1972 (min. and max. of 29 sites in August); ref.n: Sieghardt and Maier 1985 (min. and max. of season).

Dykyjova (1979) measured a increase in Ca content of 0.54 % to 1.60 % in the shoot from June to August. Bayly and O'Neill (1972) found an increase from 0.14 % in May to a peak in July of 0.29 % and thereafter a decrease to 0.18 % in August.

2.4.6.7 Magnesium

Data for the concentration of magnesium (Mg) in the habitat of *Phragmites* are given in Table 19 and 20.

TABLE 19. Ranges of concentrations of Mg in the surface water in
-1
Phragmites stands in mg.l .

REFERENCE

9.4 - 13.1	(a)
10 - 16	(b)
4.0 - 25.0 (av. 10.5)	(c)
49.23	(d)

ref.a: Bayly and O'Neill 1972 (during the season); ref.b: Kaul 1984; ref.c: Banoub 1975; ref.d: Ulehlova et al. 1973 (mean of 5 sites, during 2 years).

Bayly and O'Neill (1972) found a slight increase in the Mg concentration in the water from May to July. Banoub (1975) found the same Mg levels within and outside of the reed stand.

TABLE 20. Ranges of Mg concentrations in the soil in a *Phragmites*
-1
stand in mg.kg dry weight.

	TOTAL Mg	EXTRACT (1N ammonium acetate)	REFERENCE
	4700 - 7900	360 - 1540	(a)
bottom soil	600		(b)
sapropel	592		(d)
	48.1 - 634.8		(e)

ref.a: Bayly and O'Neill 1972 (during the season); ref.b: Kaul 1984; ref.d: Ulehlova et al. 1973 (mean of 5 sites, during 2 years); ref.e: Ho 1981 (min. and max. of 4 sites).

Bayly and O'Neill (1972) found a minimum in the extractable Mg concentration in the soil by the end of July.

The Mg concentration in the plant tissue gives the following picture (Table 21).

Bayly and O'Neill (1972) measured a decrease in the Mg concentration in the shoot from 0.86 - 0.97 % to 0.46 - 0.73 % from May to August. Over the same season (to October) Dykyjova (1979) found a decrease from 0.14 to 0.08 %. On the contrary Wallentinus (1973) reported that Mg content in the leaves is highest at the termination of the growing season.

TABLE 21. Ranges of Mg concentrations in the different organs of *Phragmites australis* in % dry weight.

ORGAN		REFERENCE
rhizomes	0.20 (0.12)	(g)
	0.401	(d)
	0.108 - 0.136	(e)
roots	0.47 (0.30)	(q)
	0.34	(d)
	0.134 - 0.300	(e)
roothair	0.45 (0.30)	(g)
stem	0.13 (0.06)	(g)
	0.030 - 0.060	(h)
	0.158 - 0.194	(e)
	0.028 - 0.060	(j)
	0.05 - 0.12	(l)
young plants	0.077	(d)
ripe plants	0.038	(d)
dying off plants	0.0690	(d)
leaves	0.33 (0.20)	(q)
	0.120 - 0.209	(h)
	0.15 - 0.41	(i)
	0.428 - 0.486	(e)
	0.118 - 0.205	(j)
young plants	0.15 - 0.34	(l)
	0.216	(d)
	0.270	(d)
	0.231	(d)
	0.46 - 0.97	(a)
stem + leaves	0.067	(f)
	0.08 - 0.14	(j)
	0.058 - 0.152	(k)
poor soil	0.08	(j)
rich soil	0.17	(j)
panicle	0.302 - 0.342	(e)

ref.a: Bayly and O'Neill 1972 (during the season); ref.d: Ulehlova et al. 1973; ref.e: Ho 1981 (min. and max. of 3 sites); ref.f: Auclair 1979; ref.g: Kovacs et al. 1978 (the data between brackets are from 1 year later); ref.h: Kvet 1973a (min. and max. of 14 sites); ref.i: Allen and Pearsall 1963 (min. and max. of 11 sites); ref.j: Dykyjova 1979 (min. and max. of 14 sites at the peak of the growing season; the poor soil represents a sandy soil, the rich soil a deep layer of sapropel); ref.k: Van der Toorn 1972 (min. and max. of 29 sites in August); ref.l: Sieghardt and Maier 1985 (min. and max. of season).

2.4.6.8 Iron and Manganese

Little is known about the habitat characteristics of *Phragmites* concerning iron(Fe) and manganese (Mn). Lanning and Eleuterius (1985) measured in 5 sites the concentration in water of Fe and Mn. The range for Fe is 0.15-0.42 mg/l and for Mn 0.05-0.09 mg/l.

No data are available for the Fe and Mn concentrations in soils in a *Phragmites* stand.

Concentrations of Fe and Mn in *Phragmites* tissues are presented in Table 22.

TABLE 22. Ranges of Fe and Mn concentrations in different organs of *Phragmites australis* in mg.kg⁻¹ dry weight.

ORGAN	Fe	Mn	REFERENCE
rhizomes	300 (545.18)	57.0 (52.63)	(b)
	370 - 640		(d)
roots	1390 (4903)	253 (278)	(b)
	2730 - 14390		(d)
roothair	1842 (6434)	402 (433)	(b)
underground organs		26 - 232	(e)
stems	120 (88)	59 (61)	(b)
	110 - 160		(d)
leaves		10.2 - 51.5	(e)
	136 (129)	166 (125)	(b)
	100 - 360	<50 - 660	(c)
	140 - 330		(d)
stems + leaves		24.7 - 206	(e)
	171	125	(a)
panicle	150 - 190		(d)
		37.0 - 89.7	(e)

ref.a: Auclair 1979; ref.b: Kovacs et al. 1978 (the data between brackets are from 1 year later); ref.c: Allen and Pearsall 1963 (min. and max. of 11 sites); ref.d: Ho 1981 (min. and max. of 3 sites); Baudo and Varini 1976 (min. and max. of mean monthly levels from 2 sites during the year).

Iron concentrations were greater in leaves than in stems but were substantially lower than those in roots (Kovacs et al. 1978, Ho 1981). Auclair (1979) reported that the Fe and Mn contents of plant tissues were highly correlated with soil organic matter. Also a high correlation was found between iron in tissues and K, Na and Ca in the soil. The concentrations of Mn, in the shoot of reeds were lowest at the beginning of growth and conformed to rise until seed set whereas the underground portions showed the opposite trend (Baudo and Varini 1976). Ho (1981) reported similar observations for Fe and other nutrients in the stem and leaves of reeds but found no consistent seasonal pattern for the roots and rhizomes.

2.4.6.9 Other Micronutrients

The essential micro-nutrients zinc (Zn), copper (Cu), molybdenum (Mo), and silicon (Si) are discussed with regard to their concentrations in the water in reed stands and to their concentrations in *Phragmites* tissues. Data concerning pollution of heavy metals are discussed later in "Contaminant uptake".

The status of Zn and Cu dissolved in the water in a reed stand is summarized in Table 23.

TABLE 23. Ranges of concentrations of Zn and Cu in the water in a
-1
Phragmites stand in ug.l .

	Zn	Cu
surface water	39.9	15.3
interstitial water 0-10 cm	100.0	45.8
interstitial water 10-20 cm	60.1	15.3

These data are from an unpolluted lake (Schierup and Larsen 1981). Other data concerning heavy metal pollution are discussed later. No data on micronutrients are available about the soil condition in *Phragmites* stands.

TABLE 24. Ranges of concentrations of Zn, Cu, Mo, and Si in different
-1
organs of *Phragmites australis* in mg.kg⁻¹.

ORGAN	Zn	Cu	Mo	Si	REFERENCE
rhizomes	14.0				(a)
	20.72	3.72			(a')
	37.0				(a)
roots	112.0	21			(a')
	55.0				(a)
	136.0	28			(a')
stem	17.0				(a)
	14.0	1.0			(a')
		0.4- 2.2			(b)
	20-45	8 -25			(c)
				6000	(d)
			0.2-0.5		(b)
leaves	22.0				(a)
	20.0	3.0			(a')
		1 - 3.5	0.2		(b)
				52600	(d)
	25-40	25 -32			(c)
stem + leaves	112	3			(f)
panicle		0.2- 2.4	0.2-1.3		(g)
				61500	(c)

ref.a: Kovacs et al. 1978 (ref a' = ref a 1 year later);
ref.b: kufel 1978 (during the season); ref.c: Larsen and Schierup
1981 (during the season); ref.d: Lanning and Eleuterius 1985;
ref.f: Auclair 1979; ref.g: kufel and kufel 1980 (min. and max.
of 37 sites).

The Zn concentrations was reported to be negatively correlated
with Na and P in the sediment. No significant correlations
existed between Cu and edaphic factors (Auclair 1979). kufel and
kufel (1980) found no relationships between the concentrations of
Cu and Mo in plant tissues and those in the substrate.

Silicium contributes to the physical stability of stems and
leaves. The Si concentration represents 65% of total ash in the
leaves, 19% of total ash in the stem and 83% of total ash in the
panicle (Lanning and Eleuterius 1985).

Seasonal influences in metal content may be important. Zn in
leaves and stems and Cu in stems was reported to be at the
maximum during the growing season and declined thereafter (kufel

1978, Larsen and Schierup 1981). Kufel (1978) found a general decrease of metal concentration from May to August. But Cu in leaves was relatively constant throughout the season (Larsen and Schierup 1981). On the contrary Baudo and Varini (1976) reported that the concentrations of Cu in the shoot of reeds were lowest at the beginning of growth and conformed to rise until seed set whereas the underground portions showed the opposite trend.

There is no indication that situations of deficiency in micronutrients arise, not even in a peat soil. This is possibly due to the very extended root system with the numerous highly ramified adventitious roots, which arise from the vertical rhizomes. Especially in a peat soil these roots form a dense mass and have an important function in nutrient uptake (Van der Toorn 1972).

2.5 Ecology

2.5.1 Plant communities

Phragmites australis grows in marshes, swamps, wet waste areas, along bayous, streams, lakes, ponds, and ditches. In Europe it belongs to those plant communities being syntaxonomically classified as Phragmitetea due to the high frequency of *Phragmites australis* in phytosociological reviews (Tuxen 1982). *Phragmites australis* occurs on almost every soil type as long as it is moist enough but appears to do best in firm mineral clays in proximity to the water table. Bibby and Lunn (1982) describe 5 moderately distinct groups in which reed can form extensive mono-dominant stands:

- artificial (clay pits, silt settling lagoons, industrial waste lands, dredged material disposal sites, newborne polders)
- lakeside
- estuarine (upper reaches of estuaries, tidal sections of rivers, with a periodic inundation with brackish water)
- coastal (reed encroachment on occlusions of tidal creeks, rivers and flood plains with a shallow flooding)
- inland

2.5.2 Ecotypic variation

The size of the aerial stems and rhizomes, stem coloration, inflorescence size, and number and weight of viable seeds are obviously influenced by the environment. So *Phragmites australis* is a polymorphic species. Previously proposed taxonomic variations such as *gigantissima*, *stolonifera* and *flavescens* are apparently ecotypes (Haslam 1972). Haslam (1970b) distinguished two basic populations:

1. restricted
2. optimal.

The one termed 'restricted' consists of short, depauperate plants. The restricted stands occur because of one or more factors creating environmental stress. The optimal populations represent the typical form of *P. australis*. The restricted stands occur on higher grounds where the rhizomes are not submerged in the water. Rhizomes are short because of lack of water and nutrients (Haslam 1972). Upland stands are exposed to frost that may kill buds (Van der Toorn 1971). *Phragmites* in a harsh environment tends to have limited carbohydrate reserve (Buttery and Lambert 1965), which accounts in part for the less viable rhizomes. Shaded *Phragmites* produces a somewhat distinctive ecotype with flaccid leaves and an increased blade weight, while the characteristic ribbing is absent. Excess salinity also produces depauperate plants. The smallest *Phragmites* recorded by Haslam (1970a) had nearly prostrate shoots about 5 to 15 cm long. These plants were growing in hard, rather salty, sandy soil. The optimal populations occur in more favorable environmental conditions and represent the typical form

of *Phragmites* (Haslam 1970b, 1970c, 1972). Waisel and Rechaw (1971) obtained seeds from a halophytic population. These germinated in salt water of up to 2.3 % Cl. Germination of seeds from a glycophytic population was severely inhibited at this concentration.

In The Netherlands Van der Toorn (1972) distinguished two different ecotypes based on transplantation studies:

1. a peat ecotype consisting of reed with short shoots and a high shoot density occurring in peat marshes.
2. a riverine ecotype consisting of reed with long shoots and limited shoot density, occurring mainly in fresh water tidal areas.

The riverine ecotype compared with the peat ecotype has (1) a higher above-ground production, (2) a greater tolerance for tidal submergence, (3) less tolerance for ground frosts in spring and (4) a greater sensitivity to infestation by the moth *Archamia geminipunctata*.

Dykyjova et al. (1973) recognized that the nearly cosmopolitan distribution of *Phragmites* must lead to both genotypic and phenotypic variation.

2.5.3 Production

Production of *Phragmites* is dependent on different habitat parameters. Generally it is supposed that the presence of light, and the availability of water and nutrients are important factors for a good reed growth. Reflection of light on the water surface can increase the amount of light which the leaves receive. That is why production on the border of a reed stand is often larger than in the middle (Meulemans 1982). Sieghardt et al. (1984) also found the lowest biomass in the middle. However, Mochnacka-Lawacz (1974a) found that the reed in the middle of the stand was most productive. The reed on the shore was characterized by the lowest biomass values, which she attributes to the periodical inundation with water.

Production can be measured by a lot of parameters e.g. shoot density, shoot diameter, dry weight and fresh weight of total biomass or of particular plant parts, height of the reed, number of leaves per shoot, and growth rate. Relations between these parameters and effects of fertilizers, water level, interaction with other species, and management will be considered. Several

of the ways to estimate biomass are destructive and time consuming. Ihse and Granelli (1985) developed a method to estimate reed biomass through spectral reflectance measurements. They found a linear relationship between the reflectance ratio² and the dry weight of the green biomass per m².

There seems to be a relation between the log of the shoot diameter and the log of the shoot density. This relationship is the result of an influence via the rhizome. In spring first the thickest buds develop, depressing the development of other buds (Mook 1982). The potential weight of a particular shoot can be estimated by its height and by its diameter. And so the potential crop can be calculated for each combination of shoot density and mean shoot height (Kauppi et al. 1983) and of shoot density and mean shoot diameter (Mook 1982). This value is always

-1
similar, average 2250 g(dr.w.).m². But during the season in the field usually lower values are found at high shoot densities. Mook (1982) described this phenomenon of self-thinning as follows:

"When the plants have reached a certain height, the density decreases because some plants die off. Smallest plants die first. So the mean plant weight increases, but at the same time the plants keep growing

2
and it appears that the total biomass per m² increases with decreasing shoot density. Tests indicated that the status of nutrition has no influence on the rate of thinning, but only determines how far the thinning goes on. Damages give a tendency to increase the density the next season. This increases its competitive power, depressing the invasion of other species. On the other hand absence of damage gives a tendency to decrease the shoot density gradually and so on the potential crop will increase."

Van der Toorn and Mook (1982) and Mook and van der Toorn (1982) describe the effects of various environmental agents that cause damages on reeds and their effects on biomass relationships. They studied an experimental field over a period of 5 yrs. Three treatments were applied: burning in spring, mowing and removal of shoots in winter and no disturbance. Each of the three treatments were applied in a wet as well as in a dry area. Also other damages occurred caused by ground-frost and presence of moth larvae. The reaction on damage appeared to be essentially the same, regardless of its cause. An early damage, as caused by burning and early ground-frost (end of April, beginning of May), leads to replacement of shoots arising from underground nodes;

late damage, by a moth and late ground-frost (end of May) leads to the formation of side shoots on the aboveground nodes. During the season self-thinning of shoots was found in the treatments that showed high shoot densities as result of damage by burning and by early ground-frost.

Shoot densities range normally from 100 - 400 shoots.m⁻².
 Extremes for aboveground biomass of *Phragmites australis* are 600 g (dr.w).m⁻² (Dykyjova and Kvet 1978) and 3975 g (dr.w).m⁻² (Ho 1979). But, for temperate regions most values vary between 1000 and 3000 g.m⁻² (Ingram et al. 1980).

Dykyjova and Kvet (1978) compiled from several authors some production data for *Phragmites*. The extremes between these data exist are given in Table 25.

TABLE 25. The ranges of seasonal maximum biomass (fresh weight) and net production of aboveground and underground plant parts of *Phragmites australis*.

	SEASONAL MAX. BIOMASS	NET PRODUCTION
	-2 g.m	-2 -1 g.m .yr
aboveground (S)	600-3500	600-3700
belowground (R)	1600-8000	500-3000
total	2200-9500	1100-6700
R/S biomass ratio	0.9- 2.0	
R prod./ S biom ratio		0.5-1.0
average ash content	10 %	
Net org. production		-2 -1 1000 - 6000 g.m .yr

Belowground production was estimated by Roman and Daiber (1984) as the annual increment (max. biomass - min. biomass). This resulted in a mean value of 5800 g.m .yr . Hopkinson et al. (1978) give a loss rate of dead *Phragmites* material of 4.7 mg .
-1 -1
g .day .

It is clear that the R/S ratio is much higher in winter. In the literature there is some confusion about the use of root/shoot ratio, rhizome/shoot ratio and total underground biomass/shoot ratio. Dykyjova and Kvet (1978) analyzed some of these ratios and found that:

"the rhizome/shoot ratio seems to be small in biotopes with a fluctuating water level, which become limosal to terrestrial in late summer to fall; but this ratio becomes three times higher in biotopes with a stabilized hydrological regime. The dependence of the root/shoot biomass ratio on habitat seems far less clear. The total underground biomass, however, seems to be positively related to the supply of mineral nutrients from the soil, especially to that of nitrogen (regression coefficients of 0.787 and 0.884 for rhizome and root biomass respectively); the root biomass was positively correlated to the content of total carbon in the soil."

The amount of soil which is available to one seedling has a great influence on its development. Szczepanska (1977a) tested

three different levels of soil volume ranging from 13 l to 100 l. The surface area was in all levels the same. All values of the following parameters: mean height of 3 highest shoots in the pot, number of shoots produced, dry weight of aboveground part of the plant, dry weight of the aboveground parts of the plants per m^2 , increased. The dry weight of one shoot in the pot increased to the third level, after which it decreased, due to self-thinning.

The effect of potassium, nitrogen and phosphorus on the production of *Phragmites* has been studied by Ulrich and Burton (1985) and Bornkamm and Raghi-Atri (1986). They found potassium to have no significant effect on biomass. But nitrate and phosphorus both stimulated strongly plant growth. Bornkamm and Raghi-Atri (1986) grew *Phragmites* plants from the field in quartzsand with a nutrient solution with different N- and

P-levels. As compared with the standard solution (2.88 mM N l⁻¹ ;

1.43 mM P l⁻¹) low levels of N (0.14 mM l⁻¹) gave a clearly lower shoot length after the third year, whereas the high N level

(14.76 mM l⁻¹) gave a higher shoot length. At the high N level the shoots also were thicker but seemed to break more easily as compared with the standard level (Raghi-Atri and Bornkamm 1980).

High additions of phosphorus (16.62 mM l⁻¹) had a dragging effect on shoot length and shoot density in the first year of culture (Bornkamm and Raghi-Atri 1986). High P levels also caused thin stems, with less sklerenchyma and a lower specific weight than

the stems from solutions with the standard (1.43 mM P l⁻¹) or low

(0.14 mM P l⁻¹) P level. Consequently they also broke more easily (Raghi-Atri and Bornkamm 1980). However, in other investigations (Raghi-Atri and Bornkamm 1979), the same authors demonstrated that high P level can induce thick and thin stems.

Also the presence of other species will have an effect on production. In a comparative study during 4 years of a monoculture of *Phragmites* with mixed cultures with *Carex hudsonii* (Szczepanska 1977b), the mean height of *Phragmites* and its number of shoots were higher in the monoculture. The weight of one shoot was slightly lower in the monoculture in the first 2 years but higher afterwards. Also in experiments with *Typha latifolia*, *Phragmites* is not favored by a presence of *Typha*, in growth rate as well as in production (Szczepanska 1977c).

2.5.4 Decomposition

Especially in reed stands, which are often more or less monospecific, the nature of its decomposing plant parts may act a role itself in the habitat. Each autumn the aboveground biomass will die off. Individual rhizomes can live 3 - 6 or even more years (Haslam 1973).

Imhof (1973) estimated that in a *Phragmites* stand with an energy fixation of $63,000 \text{ kJ.m}^{-2} \text{ .yr}^{-1}$, the majority of the production is utilized by the microbial decomposers. Only a small portion of the energy is apparently utilized by phytophages, and the estimated intake by insects is $170-250 \text{ kJ.m}^{-2} \text{ .yr}^{-1}$.

In a review on the decomposition of aquatic macrophytes Polunin (1984) gives full attention to the way microorganisms and detritivorous invertebrates act in this process. Best (1982) studied the changes in chemical composition of *Phragmites australis* leaves during decomposition under laboratory conditions. Analyses of the water in which dead reed leaves have been immersed during up to 147 days, showed that total carbon and total nitrogen increased more than in the controls. NO_3^- decreased, while NH_4^+ increased initially, but decreased later.

These increases of C and N were clearly due to the presence of bacteria in the mud, but also the leachate of the decomposing plant litter increased the nitrogen concentration of the overlying water. Decomposition is highly influenced by the salinity. The higher the salinity, the lower the decomposition rate (Reice and Herbst 1982). A comparison of the decomposition of *Phragmites* leaves in clean streams with the decomposition in a stream polluted with industrial, municipal and agricultural wastes and with a high phosphate concentration, resulted in a lower decomposition rate for the polluted stream (Herbst and Reice 1982). It was also found that the colonization rate by macroinvertebrates was lower in the polluted stream. The phenomena of colonization rate seemed to be more important for decomposition than the faunistic composition, richness or diversity. Larsen and Schierup (1981) found a faster decomposition in the sewage-polluted lake than in the oligotrophic lake, however.

The deposition of organic matter in a reed stand can also be of an allogenic character. Especially emergent plants enhance the

accumulation of organic matter by increasing deposition and reducing erosion. On high tidal marsh dominated by *Phragmites* an annual rate of 17.1 mm has been estimated (Polunin 1984).

When plant remains are added to the substrate, biomass production of young *Phragmites* plants is depressed (Siczeanska 1977b). This occurs mainly during the first weeks of decomposition, when phytotoxic activity may be higher. Thus 20 g *Phragmites* litter per 1 m² reduced the production by one seedling of *Phragmites* during 3 months from 0.63 to 0.004 g dry weight. However in nature it will rarely happen that substances of dying plants affect young plants, because the period between autumn and next spring may be sufficient for leaching and decomposition of phytotoxic substances (Kuiters 1987).

2.5.5 Succession

Phragmites australis is a common reed swamp species that usually falls between the hydrophyte and shrub (carr) stages of a hydrosere (Haslam 1972). The tangle of rhizomes and adventitious roots requires extensive space, leaving little room for invaders. Buildup of litter within the stand discourages seed germination of other species (Haslam 1971a). Additionally, optimal populations normally consist of pure stands. *Phragmites* can grow in water depths that discourage most invaders. *Phragmites* can invade bare areas created naturally or by men. However, invasion does not normally occur if an area is inhabited by other species. Also a salt marsh, of which the normal tidal prism has been restricted, will change in a *Phragmites* dominated marsh (Roman et al. 1984). Where *Phragmites* grows in a tidal area, rapid accumulation of silt may lead to a rising of the land level, which can confine flooding to spring tides (Bibby and Lunn 1982).

But *Phragmites* will tend to persist in areas it no longer dominates (most mixed stands). Then, shoots from 3-year rhizomes are small and 4-year rhizomes are mostly dead. While in a pure stand individual rhizomes live 3 - 6 or more years (Haslam 1973). Where *P. australis* is the sole dominant, shoot density is usually over 100 per m². However, annual variations in density and height are considerable, depending upon conditions of the previous year (horizontal rhizome and wide bud development) or the current environmental status (Haslam 1970b).

Drainage causes a lower plant height and smaller plant density (Kamio 1982). When a pure stand of *Phragmites* is drained, silted in or loses the ground cover of water by other means, competitors will appear. *Phragmites* will tend to cease invasion, but will

persist for a long time in most normal successional sequences. A successional study of sedge-meadow by Weaver (1960) illustrates this point. Reinink and Van der Toorn (1975) and Van der Toorn (1982) concluded that good reed growth is possible even in dry areas where the water level fluctuates between -30 and -90 cm in summer and between -20 and -30 cm in winter. However growth is restricted by frost and insect damages. Presence of reed leaf litter and reed itself inhibits germination of seeds of other species (Van der Toorn and Reinink 1978). As conditions become more xeric, the plants become more depauperate. Invasion of a stand of *Phragmites* by broad-leaved species would, because of more shading of young reed shoots, decrease the persistence of *Phragmites*.

Also grazing by vertebrates like nutria (Boorman and Fuller 1981) or invertebrates (Van der Toorn and Reinink 1983) can cause a decline of the reed tolerating an invasion of other species. When the reed stand was burned, which killed the insects, succession was stopped and no invasion of other species occurred (Van der Toorn et al. 1983).

When *Phragmites* was cultivated with *Typha latifolia* (Szczepanska 1971; Szczepanska and Szczepanski 1982), *Schoenoplectus lacustris*, *Equisetum limosum* (Szczepanska 1971) or *Carex hudsonii* (Szczepanska 1977a), its production was reduced considerably.

2.5.6 Diseases

Numerous fungi have been isolated from *Phragmites*, primarily from dead and decaying aerial shoots. Fungi on the upper sections of the submerged portions of old culms possibly are responsible for the eventual weakening and fall of the stems (Taligoola et al. 1972, Apinis et al. 1972). Haslam (1972) gives an extended list of the occurrence of fungi. She listed 12 ascomycetes, 3 basidiomycetes and 16 fungi imperfecti. *Claviceps* infection is common, especially in wet summers e.g., up to 20% in Switzerland (Hurliman 1951) and to 50% in Britain (Haslam 1972). In addition, *Claviceps* has been noted on *Phragmites* in Sweden (Gustafsson and Simak 1963) and in Britain (Mantle 1969). *Ustilago grandis* has been reported in Europe (Durska 1970, Krolikowska 1971). Infested shoots have shortened internodes and a lower transpiration, that can decrease to 1/3 of the value characteristic of healthy plants (Szczepanski 1978). Infestation by the rusts *Puccinia phragmites* and *P. magnusiana* causes a disturbed nitrogen utilization. The decrease of N content in leaves is proportional to the infestation and can be decreased by

30% on the average.

Deightonella arundinacea and *Steneotarsonemus phragmitidis* can reduce the breaking strength of the stems by causing a lack in the thickening in the stem and warts at the base respectively (Haslam 1973). Various insects have larvae growing in reed stems. In Britain they are called reed bugs. Severe infestation of *Arenostola phragmitidis* occurs in those sites, which have a large amount of litter as the eggs overwinter on litter (Haslam 1973). Damage is slight to moderate but can rise up to an 80% kill. As reed bugs eat the meristems and young tissues and as infestation is usually in the lower 30 cm of the stem, only young shoots tend to be destroyed (Haslam 1970a). In The Netherlands, *Lipara lucens*, a fly, is restricted to *Phragmites*. Eggs are deposited on the leaves. The larva induces a gall in the shoot apex where it overwinters. Normally plants with a small (3 to 4 mm) diameter are attacked (Mook 1971). *Giraudella inclusa*, a gall midge, forms no gall but the larvae live in the stems in structures resembling rice-grains (Haslam 1972). Mook (1971) examined reed stems in the polder Zuidelijk Flevoland, The Netherlands; 53% of the stems contained these larvae. Thicker stems were more often attacked and contained more larvae per stem than stems of smaller diameter. *Archana* spp is a moth whose larvae bore into and devour inner tissues of the internodes of young shoots (Durska 1970). The larvae occurred in 41% of the stems observed in The Netherlands (Mook 1971). *Archana geminipunctata* has a strong preference for wide shoots as pupation does not take place in shoots with a diameter less than 5.5 mm (Van der Toorn 1979a). Infestation causes retarded growth of leaves and shoots and lowered the maximal shoot biomass by 25-35% (Mook and Van der Toorn 1982). It can kill up to 80% of the apical parts of the reed shoots (Mook and van der Toorn 1985). Burning and mowing in winter destroys and removes the eggs, which overwinter on the reed shoots. As the larvae do not migrate to other plants after hatching in May, these treatments control the moth (Van der Toorn and Mook 1982). *Rhizedra lutosa*, another moth, whose larvae live in and feed from the rhizomes may also prefer the widest rhizomes. Heavy infestations gave losses in yield of 45-60% (Mook and Van der Toorn 1982). After a season with heavy infestation with both of these moth species, the rhizomes have narrower shoots in the next spring (Van der Toorn 1979a). *Rhizedra lutosa* can not survive in wet habitats, so infestation with this species is only important in dry areas (Van der Toorn and Mook 1982; Van der Toorn et al. 1983). *Hyalopterus pruni* is an aphid that uses *P. australis* as a secondary host, with *Prunus* being the primary host (Mook 1971).

2.5.7 Mechanical limitations

Although *Phragmites* has the capability to grow extensively in bare soils of almost every nutrient status, as long as the water level is high enough, there are several natural mechanical factors which restrict stands. So, *Phragmites* has a low tolerance for both strong wave and current action (Haslam 1972). When reeds are broken off by wave action, the rhizome is impeded which prevents proper bud formation (Haslam 1970c). Where *Phragmites* grows in a tidal area, rapid accumulation of silt may lead to a rising of the land level, which can confine flooding to spring tides (Bibby and Lunn 1982).

Also biological factors can result in mechanical limitations. Within the last several years, pollution in some Swiss lakes has become severe and has produced thick mats of algae. As the water level decreases, the mats are stranded and crush the young aerial shoots of *Phragmites* (Klotzli 1971). The effect of grazing by vertebrates and invertebrates has been reported already in "succession".

2.6 Propagation

2.6.1 Generative propagation

The amount of seeds produced by reed can be very large but also very variable (Szczepanski 1978). Viability and germination is very variable. Seed germination is highly variable, ranging from very poor to 100% (Haslam 1972). Gustafsson and Simak (1963) used X-ray photography to determine viability of seed. Only 5% of all florets photographed were viable.

For seed germination and proper seedling development, certain conditions must exist. The soil must be wet, at first, not flooded more than approximately 1 cm depth (Haslam 1971c, 1972). Szczepanski (1978) still found germination with a water cover of almost 1 m, although it was retarded by 45 days. Severe frost must be absent. Optimal germination also requires high levels of

light and temperature (25 - 35 °C) (Van der Toorn 1972). Rate of germination is temperature dependent: at low temperature germination time is prolonged (Szczepanski 1978). Application of varied temperatures (20 °C during 8 h light and 10 °C during 16 h

dark) gave a maximal germination (Van der Toorn 1972). The nitrogen and phosphate content of the soil must be high too. If the water is more than 3 cm below a seedling, phosphorus deficiency occurs. Open areas are necessary. Seedlings may occur in areas recently disturbed by man or in upland areas where plants have been removed by frost. But there, they are usually not successful, as competitors appear later in the year and shade out the seedlings (Haslam 1971c, 1972).

Time of dispersal also is important, which takes place under natural circumstances at the beginning of winter. Szczepanski (1978) noted that it was not possible to induce germination before mid February.

Chapman (1960) found best germination in 1% NaCl. Seedlings, however, require less than 0.5 % salt water for adequate survival (Haslam 1971c, Harradine 1982). Waisel and Rechaw (1971) obtained seeds from a halophytic population and these germinated in salt water of up to 2.3 % solution. Germination of seeds obtained from a glycophytic population was severely inhibited at this concentration.

Seed planting is discouraged because of the low germination rates (Haslam 1972). However, in The Netherlands *Phragmites* has been sown on very large areas in the newly reclaimed IJsselmeer polders, in order to make the soil more suitable for agricultural crops (see: "Use by men") (Van der Toorn 1982).

So, seed germination and seedling development is dependent of a variety of factors:

- the fertility of the seed: low in high polyploid level
- abnormal pollen formation
- injury by insects of seeds and panicles
- unfavorable weather conditions during flowering and seed ripening.
- during germination
 - * temperature regime
 - * light
 - * moisture
 - * salinity
- during seedling development
 - * additional N and P supply

2.6.2 Vegetative propagation

Vegetative reproduction can take place in two ways, i.e. from buds in the rhizomes and regenerative from meristemic tissue in shoot nodes. The last way is common in places where reed is grazed or damaged by the moth *Archanara*. It is also possible that additional shoots are formed on broken stems floating in water. Each node can develop into a new shoot (Szczepanski 1978).

Vegetative extension is strongly promoted by stolons, the creeping shoot at the periphery of the reed plant, growing on rather bare ground. Artificial sowing by airplanes on the newly reclaimed polders in the IJsselmeer, The Netherlands, produced only a few seedlings per are; these formed a dense reed mat within three years by means of stolons (Van der Toorn 1972).

It is important for young plants to develop 10-12 shoots with subsequent rhizomal development to survive frosts. The young shoots may be killed, but if frost-tolerant horizontal rhizome development has occurred, new shoots will be produced.

Old reed beds may be very old (ca. 1000 years). Vegetative spread is here considerable (Haslam 1973).

Commercial propagation may be accomplished by seed or portions

of rhizomes (with or without roots) before spring growth is initiated. Young green shoots may be planted in May or June. Rhizomes bearing dead aerial stems and transplanted in spring provide the best results (Haslam 1972). Veber (1978) gives an extended survey on the artificial propagation and cultivation of *Phragmites*. Different types of vegetative propagation are discussed as by

1. dividing a reed stolons,
2. layering reed shoots,
3. stem cuttings, where the nodal meristems remain intact,
4. rhizome cuttings

Propagation by seed is also discussed.



Photo 3. Dead reed stems covering part of Times Beach, awaiting decomposition. Courtesy Joop M. Marquenie.



Photo 4. Harvest of reed stems for thatching and fencing in the Netherlands. Debris is burnt in order to prevent diseases and to maintain the reed stand. Courtesy Pim de Kock.

Chapter 3

Contaminant uptake

Phragmites australis can withstand environmental extremes (Kufel and Kufel 1980) including the presence of toxic contaminants and, thus, may be the first plant to invade and vegetate successfully areas which cannot support the growth of other plant species (Ricciutti 1983). The invasion of disturbed areas by reed beds represents an important stage in hydrosere succession (Ingram et al. 1980, Bibby and Lund 1982) which entraps sediment and organic debris and prevents erosion, thus forming the initial process of natural restoration of a disturbed wetland to productivity. The establishment of reed beds, thus, may represent a significant step in the reclamation of wetland creation and confined upland disposal sites containing contaminated dredged material. Very little is known about the uptake of contaminants by reeds, the physiological effects of contaminants on the growth and development of reed beds, or the potential for contaminant entry into the food chain via reed beds.

3.1 Heavy metals

Most of the literature on heavy metal accumulation by *Phragmites australis* is concerned with trace metals essential for plant nutrition, especially copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn), of which only Cu and Zn are commonly cited as being toxic in higher concentrations. Table 26 summarizes the concentrations of these and seven other metals that have been analyzed in reeds.

TABLE 26. Ranges of concentrations of Zn, Cu, Pb, Cd, Sr, Al, Cr, Co and Hg in different organs of *Phragmites australis*

-1
in mg.kg .

ORGAN	Zn	Cu	Pb	Cd	REF.
rhizomes	14.0				(a)
	20.7	3.7	2.5		(a')
	37.9	2.1	<1.0	0.22	(h)
	31.4	3.1	<1.0	0.07	(h')
roots	37.0				(a)
	112.0	21	14		(a')
	244.5	10.8	9.2	1.22	(h)
	118.0	14.3	3.4	0.26	(h')
roothair	55.0	35.5- 193.5			(k)
	136.0	28	25		(a)
underground organs		85.3- 379			(a')
stem	17.0				(l)
	14.0	1.0	1.0		(a)
		0.4- 2.2	0.3-3.5		(a')
	45	25			(b)
	47.8	2.4	<1.0	<0.03	(d)
	25.4	1.3	<1.0	<0.03	(h)
		13.8- 577			(h')
		8.1- 24.3			(l)
leaves	22.0				(k)
	20.0	3.0	3.0		(a)
		1 - 3.5	1 - 2.1		(a')
	25 -40	25 - 32	0 -17		(b)
	33.7	3.1	<1.0		(c)
	40.1	2.5	<1.0		(h)
		14.7- 624			(h')
		11.8- 26.5			(l)
stem + leaves	112	3			(k)
		0.2- 2.4	0.4- 2.6		(f)
panicle	24.8		4.4		(g)
		58.4			(i)
		174 -3323			(m)
					(l)

TABLE 26. Concluded

ORGAN	Sr	Al	Cr	Co	Hg	REF.
roots	37					(a')
roothair	63					(a')
underground organs			2.00-16.0			(1)
stem	1.0			0.2-0.8		(a')
			0.64-1.98			(b)
leaves	13.0	10-220		0.4-1.0		(1)
			2.06-3.62			(a')
stem + leaves					0-35000	(e)
panicle			4.16-9.00	0.2-1.6		(b)
						(1)
						(j)
						(g)
						(1)

ref.a: Kovacs et al. 1978 (ref.a' = ref.a one year later);
 ref.b: Kufel 1978 (during the season); ref.c: Larsen and Schierup
 1981 (during the season); ref.d: Lanning and Eleuterius 1985;
 ref.e: Allen and Pearsall 1963 (min. and max. of 11 sites);
 ref.f: Auclair 1979; ref.g: Kufel and Kufel 1980 (min. and max.
 of 37 sites); ref.h: Larsen 1983 (Lake Hampen; ref.h': Lake
 Sorteso) ref.i: Gunnison 1978 (from dredged spoil); ref.j: Sarkka
 et al. 1978 (from 4 sites, on 3 dates); ref.k: Chiaudani 1969
 (min. and max. of 18 sites); ref.l: Baudo and Varini 1976 (min.
 and max. of mean monthly values at 2 sites, during the year);
 ref.m: Odum and Driffmeyer 1978.

Accumulations of Cd, Cr, Cu, Pb, and Zn generally were greatest
 in the roots and/or rhizomes and decreased in the above-ground
 plant parts. The essential trace metals were more mobile within
 the plants in contrast to Cd and Pb, which apparently
 translocated very poorly. The general trend was not consistent,
 however. Baudo and Varini (1976) found the highest mean

concentrations of Cr (6.23 ug.g⁻¹) and Cu (1466 ug.g⁻¹) in the
 inflorescence and the highest Mn (93.2 ug.g⁻¹) in the leaves.
 Schierup and Larsen (1981) also reported a high Zn content (150
 ug.g⁻¹) in the upper 20-40 cm of the stem, which contains the
 inflorescence.

High concentrations of metals in plant tissues reflected both
 the relative plant availability of the metals in sediment

(Schierup and Larsen 1981) and the degree of contamination of that sediment (Chiaudani 1969). The Cu content of leaves apparently is well regulated by the plant at environmental levels below the acute toxicity threshold, as Cu levels were similar in the leaves of plants growing on sediments of different Cu content (Chiaudani 1969). Plants growing in more contaminated areas generally had elevated levels of heavy metals in the tissues in comparison to plants growing in less contaminated areas, as would be expected (Baudo and Varini 1976, Chiaudani 1969, Larsen and Schierup 1981). Kufel and Kufel (1980) found that Pb in tissues tended to increase with increased Pb in the substrate. Larsen and Schierup (1981) concluded that "the amount of heavy metals present in the rhizosphere of sediments may considered to be the amount potentially available to plants." Data were unavailable for the overall distributions of Hg, Mo, and Ni within *Phragmites* tissues.

Substrate characteristics may significantly influence the uptake of trace metals by reeds. Schierup and Larsen (1981) suggested that the higher pH, lower redox values and higher organic contents (thus high CEC) of Lake Sorteso (Denmark) rendered the heavy metals less available than those in Lake Hampen; thus, edaphic factors formed greater plant uptake of heavy metals from lake Hampen sediments, even though metal concentrations in the sediments were lower than at Lake Sorteso.

Kufel (1978) reported that the highest concentrations of Pb and Cu in aboveground portions of reed were found during early summer and declined thereafter; Co declined only slightly throughout the season. Pb content of the leaves increased during and after the growing season, presumably as the result of atmospheric deposition (Larsen and Schierup 1981, Larsen 1983). Also Odum and Driffmeyer (1978) found higher levels of Pb on *Phragmites* leaves at shorter distances from the highway. These levels were increased with a factor 6 in the standing dead leaves and with a factor 24 in the leaf litter.

As compared with another helophytic plant *Typha latifolia* there is a tendency that the maximum levels of Zn and Cu in the underground organs are lower in *Phragmites*. But this results in a same level in the leaves and shoots. Sr seems to be better translocated to the shoots by *Typha* than by *Phragmites* (Kovacs 1982, Taylor and Crowder 1983a, 1983b).

3.2 Organic contaminants

Literature pertaining to the uptake by and effects of organic contaminants from *P. australis* is almost non-existent. Sarkka et al. (1978) reported the uptake of chlorinated hydrocarbons by reeds and other plants in Lake Paijanne, Finland. The ranges of concentrations reported for reeds were 0-267 ug.kg⁻¹ (PCB), 0-7 ug.kg⁻¹ (total DDT), and 0-4 ug.kg⁻¹ (aldrin). The organochlorine content of reeds varied widely with sampling stations (4) and dates (3) with no consistent pattern for plant uptake.

Physiological effects of pesticides on *Phragmites* also have been reported. Merezhko and Shokod'ko (1978) reported that the accumulation of DDT by reed was dependent upon the concentration of DDT in the environment and that DDT was absorbed to the level causing inhibition of metabolic activities. The levels of pesticide accumulation in the plants were unclear in both of the latter publications, however. Shokod'ko et al. (1978) reported

that DDT and BHC (lindane) decreased CO₂ assimilation in *Phragmites* and suggested that these pesticides had a specific effect in photosynthesis as well as a "total toxic effect." *Phragmites* was more resistant to DDT than to BHC. The pressure of

DDT and BHC promoted C₁₄ "outflowing into roots" in direct proportion to the pesticide concentrations. The "intensification of assimilates into roots in the presence of DDT and BHC was indicated as a "protective reaction of *Phragmites communis* Trin. to the action of the toxic agent."

Chapter 4

Utilization

4.1 Use by wildlife

The ground under a *Phragmites* stand usually has an abundant cover of litter that provides a habitat for small mammals, insects, reptiles and perhaps a few fishes such as *Ictalurus* spp. (bullhead catfish). Aerial stems provide nesting sites for several species of birds (Benton and Werner 1958, Beck 1971). Burger and Miller (1977) recorded *Plegadis falcinellus* (glossy ibis) nesting in a *Phragmites australis* - *Myrica pennsylvanica* habitat in New York, and building their nests of old *Phragmites* stems. In Australia also ibises (*Threskiornis aethiopica*, *T. spinicollis* and *Plegadis falcinellus*) were found to breed in *Phragmites* (Cowling and Lowe 1981). Both *Sterna hirundo* (common tern) and *Larus delawarensis* (ring-billed gull) were found nesting in *Phragmites* in the Great Lakes. *Larus articilla* in New Jersey was found to nest in mixed stand of *Spartina patens* and *Phragmites* (Burger and Shisler 1980). Although the Clapper Rail (*Rallus longirostris yumanensis*) gives preference to *Scirpus* or *Typha* stands, there are scattered places in the Colorado River Valley where they inhabit *Phragmites* stands (Anderson and Ohmart 1985). In England Wagtails (*Montacilla alba*) like to roost communally in winter in *Phragmites* reed beds (Fleming 1981). Bibby and Lunn (1982) found Bittern (*Botaurus stellaris*), Marsh harrier (*Circus aeruginosus*), Bearded tit (*Panarus biarmicus*), Savi's warbler (*Locustella luscinioides*) and Cetti's warbler (*Cettia cetti*) breeding in reed stands. The Graylag goose (*Anser anser*) builds its nest in reed stands, breaks of reed shoots growing around the nests, and accumulate it as nest-building material (Hudec 1973b). Also smaller birds like the reed warbler (*Acrocephalus scirpaceus*) broods in reeds (Delschlegel 1984). For the Water Pipet (*Anthus spinoletta spinoletta*) wetlands with *Phragmites* are favored as roosting places (Witt 1982). In Britain reed stands are also used as roosting sites by swallows and certain rails and sparrows (Ingram et al. 1980).

In the Louisiana marshes, *Quiscalus major* (boat-tailed

grackles), *Tyrannus* spp. (kingbirds), and *Agelaius phoeniceus* (red-winged blackbirds) occupy the *Phragmites* stands (Eifert 1959). Miller (1967) found that *Xanthocephalus xanthocephalus* (yellow-haired blackbird) is restricted in its nesting sites to emergents such as *Phragmites*.

Although many species of birds find a roosting or nesting place in *Phragmites* stands, only a few feed on it. In 33% of stomachs of Coots (*Fulica atra*) remains of *Phragmites* was found (Borowiec 1975). Geese (*Anser anser*) can eat so much of the reed that they can keep an open vegetation in the marsh (Poorter 1982). Boorman and Fuller (1981) noticed grazing by mute swans (*Cygnus olor*), *Anser anser* and *Branta canadensis* (Canada goose) and *Fulica atra*. Although Kvet and Hudec (1971) describe the effect of grazing as damage. In The Netherlands the reed stands are often visited by geese. The result of a reed stand with an open character is seen as an advantage as it leads to a more differentiated reed marsh vegetation. In spring the geese eat the young shoots, often below the water surface. When the water level is not too high they also dig the rhizomes. During the molting of the wings only reed leaves are eaten. In autumn leaves and rhizomes are eaten. Young seedlings can be pulled out in large amounts. Afterwards they start consuming the rhizomes of the older reed stems (Hudec 1973a, Poorter 1982).

Fromel (1980) stated that reed beds are of great importance for insects and spiders wintering in *Phragmites* stands. Burning and mowing decreased the density of arthropods and can so be of negative influence on the supply of food for migrating as well as for breeding birds.

To the mammals which use *Phragmites* as food source belong the muskrat (*Ondatra zibethicus*) especially when the other habitats become overpopulated (Lynch et al. 1974). *Phragmites australis* comprises a portion of the muskrat's diet throughout the Louisiana coastal marshes with highest consumption occurring in the delta and prairie marshes (O'Neill 1949). According to Errington (1941), *P. australis* is stored by muskrats in Saskatchewan marshes and is an important summer food in north-central marshes and lakes. Haslam (1970a, 1972) noted that reed is eaten in Europe by *Myocaster coypus* (nutria, coypu) which eat the rhizomes and young shoots, by *Dama dama* and *Odocoileus* spp. (deer) which eat the shoots, and *Arvicola amphibius*, the water vole, eating the exposed rhizomes and buds. They all do little harm to the reed stand and disturb only small patches (Haslam 1973). On the other hand Boorman and Fuller (1981) contributed a decline of a reed swamp to the grazing by nutria. *Phragmites* is listed by the Peking, China, zoo as a favorite food of the giant panda (Anonymus 1974). Self et al. (1974) found that captive *Odocoileus virginianus* (white-tailed deer) consumed

31.5 g of *P. australis* per day during mixed feeding trials in Louisiana, and that it provides excellent escape cover.

Ondatra zibethicus uses *P. australis* for emergency cover when lower marshes are swept by storm tides (Lynch et al. 1974). Martin (1953) considered the plant to have only low grade value as food for muskrat but to be excellent for their house building.

Joanen (1969) noted that *P. australis* is sometimes a partial constituent of *Alligator mississippiensis* (American alligator) nests.

4.2 Use by men

Phragmites is used in many different ways by men. As agricultural use it is grazed by livestock (Haslam 1972) and used as fodder (Yakubouskii and Merezkhiko 1975). In Europe as well as in the United States and Mexico it was often used in household goods and in musical instruments. Other important uses of reed are discussed below.

4.2.1 Use on the stand

4.2.1.1 Dewatering

P. australis, with its high transpiration rate, extensive rhizome formation, and negative geotropism is well suited for sludge dewatering experiments. Sludge accumulated at the Karlsruhe Nuclear Research Station, Germany, was applied over stands of *Phragmites* growing along the banks of the Rhine. After a short period of time only one-quarter of the original one m³ volume of sludge remained. The procedure was repeated until the buildup approached the nodes of the aerial stems. *Phragmites* formed new rhizomes within the sludge and flourished. successive layers of approximately 4.5 m of sludge have been dumped over certain stands over several years, but the overall height of the *Phragmites* bed has increased only 50 to 60 cm (Seidel 1971).

In the Hachirogata central polder in Japan, also *Phragmites* contributed to the drying and dissipation of the marshy and heavy

clay soil ground. Seeds were sown by helicopter immediately after the exposure of the lake bottom. In the first year the ground-water table lowered about 19 cm to about 40 cm in the next year (Kamio 1982).

Also in The Netherlands reed has been sown artificially by planes in the newly reclaimed IJsselmeer polders in order to dry the soil. The very deep root system (over 2 m deep) and the high transpiration rate promote dissipation and make the soil more suitable for agricultural crop plants. The extended root system makes the initially very weak soil better passable. The reed stand also helps to repress the introduction of other species, preventing the establishing of species, which are unfavorable for agriculture, like *Cirsium arvense* and *Cirsium vulgare*. It appeared that the reed was fairly easily to remove during and after the cultivation (Van der Toorn 1982).

Studies by Lee et al. (1976) indicating potential uses of *P. australis* in filtering and dewatering dredged material. Observations made at dredging sites indicated that the presence of thick vegetation growing on a disposal site helps to decrease the turbidity of the effluent. *Phragmites australis* was found to aid in slurry filtration when naturally present at many diked and disposal sites in fresh or brackish water. As previously observed by Seidel (1971), Lee et al. (1976) found the regenerative ability of *Phragmites* after complete burial up to 2 m of dredged material makes it a prime plant for slurry filtering. The previous authors also found *P. australis* to be useful in dewatering dredged material, particularly in areas where dredged material is deposited frequently.

4.2.1.2 Bank protection

Banks of lakes, canals and rivers are frequently submitted to erosion by wind, waves and boat wash. Although last decennia natural bank protection was replaced for a big deal by materials like concrete, steel or synthetic substances. Presently in many places bank vegetations, which aim at bank protection are developed. The growth potentials for plants in a bank habitat and so the potential to protect the shores are defined by the slope, substrate and waves from boats and wind and by human activities like boat-landings, mowing, grazing by cattle and fishery. Helophytes can protect the bank by (Bonham 1983):

1. absorbing boat wash wave energy
2. maintaining vigor and stability
3. preventing substrate scour
4. encouraging sediment deposition

A reed bed along the bank of 2 to 3 m wide can absorb 60-75 % of the energy from the waves (Bonham 1983). The dense and extended root system will prevent erosion at the bank side of the reed bed; also the thin, though, flexible stems are able to withstand wave action. The outer edge of the bed is prone to scour, however (Bonham 1983). Therefore it is advised to use other species like the Common Clubrush or Bulrush (*Schoenoplectus lacustris*) along the side of the waterway (Van Acht and Sessink 1982), in order to protect the rhizomes of the reed. The reed zone can grow to a maximum of 1.1 m deep. The clubrush zone to a maximum of 2 m deep. This way of planting is applicable at a natural bank with a slight slope. Management of the bank vegetation is usually necessary, especially to prevent infestation by insects. Burning or mowing should be done in early spring with regard to heavy wave action in wintertime (Van Acht and Sessink 1982).

4.2.1.3 Water purification

The use of *Phragmites* stands and other macrophytes in water purification has been treated by numerous authors. This concerns especially the removal of excess of nutrients (N, P) in communal, agricultural and industrial waste water. De Jong et al. (1977) showed that the purification of sewage is based on a breakdown by micro-organisms. The swamp plants function by providing attachment sites for these organisms and by the uptake of nutrients. A more sophisticated form of waste water purification is achieved in the root-zone-method (Brix 1986). A root-zone treatment plant is basically an artificial wetland consisting of a plastic lined excavation containing emergent vegetation growing in soil. In advance treated waste water, which includes the stay in a sedimentation tank must penetrate through the soil and no surface run-off must occur. When it flows through the rhizosphere the wastewater is cleaned by binding and precipitation processes in the soil and by microbiological degradation. The functions of the macrophytes is as follows (Brix 1986):

1. To supply oxygen to the heterotrophic microorganisms in the rhizosphere
2. To increase/stabilize the hydraulic conductivity of the soil

Brix (1986) selected *Phragmites australis* as a very suitable species because of the deep and dense roots and rhizomes, which create a great volume of active rhizosphere per surface area. The direct role in uptake of nutrients is negligible, as the total uptake during one growing season is only a few percent of total inflow (see: "Nutrient uptake"). Also recycling in the system takes place as the result of decay.

The system developed by Wolverton and McDonald (1982) is a combination of a vascular plant system growing in a filter bed containing anaerobic microorganisms. They called this system the "Hybrid microbial filter-vascular plant waste water treatment system". Reed was often used as vascular plant. Complex organics are broken down into simpler compounds, which can be assimilated by the reeds. Odorous volatile sulfides produced during anaerobic digestion are either removed by the plants or converted to sulfates near the surface. Other gaseous products are CO₂ and CH₄ (Wolverton 1982). Methane can be collected and

burned as an energy source or the gases flared for odor control (Wolverton and McDonald 1982). Wolverton et al. (1983) compared the effectiveness of *Typha latifolia*, *Juncus effusus* and *Bambusa multiplex* with that of *Phragmites australis* in a similar system. *Phragmites* showed to be superior in removing N, P and suspended solids.

Table 27 gives a summary of the efficiency of removal of nutrients in wastewater by *Phragmites australis*, based on several authors. It would have been valuable if every author had stated the final concentration of nutrients in the effluent in relation to the retention time and the area of the purification plant.

TABLE 27. The influence of the presence of *Phragmites australis* on waste water purification. Removal efficiency (% of influent concentration) of nutrients and solids.

T- : total
 Kj- : Kjeldahl
 O- : ortho
 TSS : total suspended solids
 TDS : total dissolved solids
 (t) : through soil
 (o) : over soil
 d : days
 m : months

TYPE OF WASTE WATER	PARAMETER	PRESENCE OF REED	REMOVAL %	RETENTION TIME	REFERENCE
sewage	Kj-N	+	99.2	17 d	(a)
		-	98.5		
	NH -N 4	+	100		
		-	100		
	T-P	+	99.3		
agricultural and domestic		-	99.2	123 d	(b)
	T-N (t)	+	91.9		
	(o)	+	87.2		
	(o)	-	69.1		
	T-P (t)	+	77.0		
	(o)	+	73.1		
	(o)	-	64.9		
	K (t)	+	86.4		
	(o)	+	78.3		
	(o)	-	35.1		
domestic	TSS	+	91.4	2 d	(c)
		-	80.0		
	TDS	+	29.3 (increase)		
		-	4.0		
	Kj-N	+	82.0		
		-	27.6		
	NH -N 3	+	95.2		
		-	7.6		
	T-P	+	54.5		
		-	11.3		

TABLE 27 Concluded

TYPE OF WASTE WATER	PARAMETER	PRESENCE OF REED	REMOVAL %	RETENTION TIME	REFERENCE
poultry abattoir	Na	+	81 (incr.)	4 d	(d)
	K	+	55 (incr.)		
	Cl	+	44 (incr.)		
	TSS	+	84		
	Kj-N	+	26		
	ND -N	+	60 (incr.)		
	3				
	NH -N	+	12		
	4				
	T-P	+	37		
domestic	O-P	+	28	13 m	(e)
	T-N	+	29		
	T-P	+	17		
	T-N	+	88		
	T-P	+	94		
	T-N	+	62		
	T-P	+	83		
	T-N	+	23		
	T-P	+	31		
	T-N	+	25		
	T-P	+	18		
	T-N	+	10		
	T-P	+	11		
	T-N	+	30		
	T-P	+	38		
	T-N	+	53		
	T-P	+	45		

(*) with *Typha latifolia* and *Carex acutiformis*

(**) natural wetland

ref.a: De Jong et al. 1977; ref.b: Radoux 1982; ref.c: Wolverton et al. 1983; ref.d: Finlayson and Chick 1983; ref.e: Brix 1986 (comparison of 8 root zone treatment plants in Denmark).

De Jong et al. (1977) found a good removal of N and P from the sewage from a campsite. The presence of vegetation had no clear influence, however except for the reduction of eutrophication of the pond. A comparison of percolation of water through the soil and flowing over the soil has been carried out by Radoux (1982). Three species were used successively: First the water had to flow through a *Typha latifolia* bed, then through a *Phragmites australis* bed and last through a *Carex acuta* bed. The presence

of vegetation had a beneficial influence on N, P, K removal, as had the system where the waste water flows through instead of superficially over the soil, so using more of the rhizome volume. In the microbial filter method of Wolverton et al. (1983) the beneficial presence of vegetation is demonstrated. The increase of total dissolved solids is due to the decay of suspended solids. Although Finlayson and Chick (1983) also found a decrease of N, P and suspended solids concentrations in the effluent, the concentration of Na, K and Cl was increased. The lignosulphate concentration in paper mill waste water was also decreased by *Phragmites*. But *Juncus pallidus* and *Typha orientalis* did do it better (Allender 1984).

Most research with regard to the utilization of aquatic macrophytes in waste water purification concerns organic pollution and macronutrients. Little has been done on their possible use for other pollutants. In the case of heavy metal pollution this will force to harvest the vegetation. We have seen that low levels of heavy metals are transported from the root system to the above-ground plant parts of *Phragmites australis*. McDonald compared the efficiency of several aquatic species in decontaminating radioactive soils and water. She showed that cesium, strontium and cobalt were absorbed by the root system of *Phragmites* but just a little was transported to the shoot.

4.2.2 Use after harvesting

4.2.2.1 Energy source

The use of aquatic plants like water hyacinth as energy source has been discussed in terms of methane fermentation. Reeds can be burned directly as a solid fuel because the low water content and the high C/N ratio. In Sweden a large project is runned to use *Phragmites australis* as energy source (Bjork and Graneli 1978, Graneli 1984). The standing crop in a reed stand is in

-2

summer 1 kg dry matter m⁻²; in winter 0.5 kg m⁻². Higher maximum

-2

biomass values have been reported up to 3.5 kg.m⁻² (Roman and Daiber 1984), but these are probably not representative for larger areas. The energy content of reed in summer as well in

-1

winter is about 5 kWh.kg dry matter. This is only 42% of the energy content of oil.

Graneli (1984) explains that lowlying wasteland can often be cultivated with *Phragmites* for local energy use, as large volumes make transportation and storage expensive. In order to make reed more compact several methods are available:

- bales, in the same way as straw (100 kg.m⁻³)
- cutting in chips of 0.5 - some cm (volume weight: 100-150 kg.m⁻³)
- powder (volume weight: 250 kg.m⁻³), this allows automatic burning
- high pressure, transformation to brickets and pellets (density: 1000 kg .m⁻³ ; volume weight: 500-700 kg.m⁻³).

Graneli (1984) thinks as compared with straw, that the energy input is only 15% of the energy output. Agricultural plants like wheat and potatoes require an energy input of 17 tot 27 %.

For local use reed is an fairly good fuel with a low ash content, a rather high energy content and a low energy input/output ratio. But as it is very bulky the transport costs should be kept low, although a distance of 100 km will not influence the energy budget substantially (Bjork and Graneli 1978).

4.2.2.2 Industrial use

Phragmites is also used for industrial purposes. In Romania (De la Cruz 1978) and the Volga delta, U.S.S.R. (Karzhavina 1975) it is used for cellulose production for the manufacture of paper and other cellulose derivates. The cellulose content is 27-69% and the mean fibre length 0.9-2.0 mm (Haslam 1973). In order to increase the tear strength and density of the paper the reed pulp has to be mixed with wood pulp (De la Cruz 1978).

4.2.2.3 Reed as building material

In the past reed was often used as building material to construct huts, walls or roofs. Now it is still satisfactory used as mats for fences, wind and sun shields, isolating material

and especially for thatching. It has a highly decorative value. Houses and buildings thatched with reed are particularly found in Japan and The Netherlands.

Thatching reed of a good quality, which is hard and resistant to decay should be fine and thin (Brandsma 1982) and have a high degree of lignification (Stant 1953). Long stems are produced in stands with a changing water table.

The costs of the thatching of a roof are very high; about Dfl
-2
100.- (begin 1987:US \$ 50.-). m². A Dutch farm often has a roof
2
of about 300-400 m². A thatched roof lasts about 40-45 years and should than be renewed (Loff 1987).



Photo 5. Estuarine *Phragmites* - *Spartina* community at the Field Verification Project (FVP) field site, Bridgeport, CT. Courtesy Joop M. Marquenie.

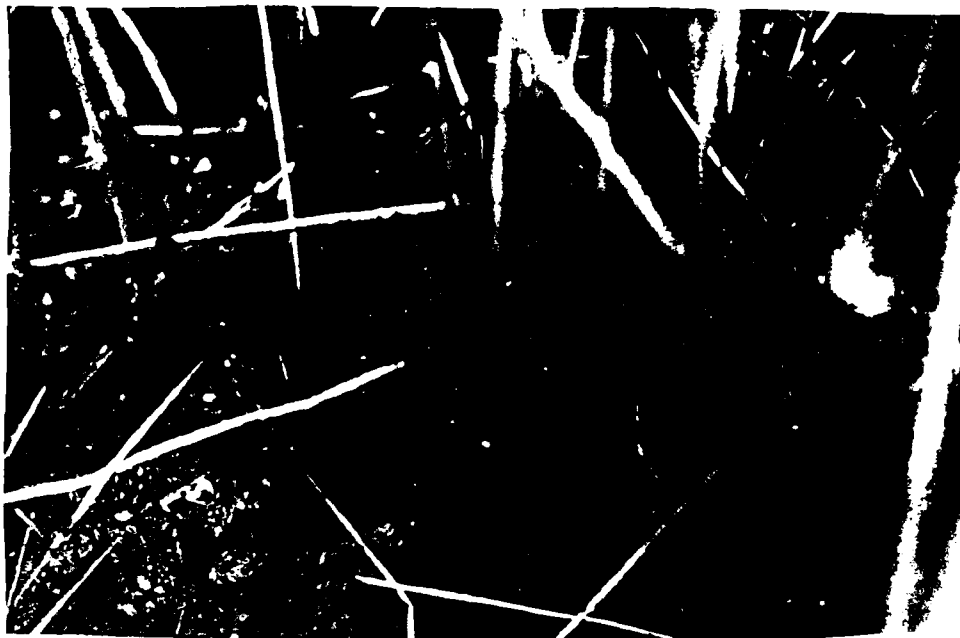


Photo 6. Marine mussels, *Modiolus demissus*, sheltered by active growing stems, rhizomes and roots of reeds. FVP field site, Bridgeport, CT. Courtesy Joop M. Marquenie.

Chapter 5

Management

5.1 Control

5.1.1 Chemical control

Twenty to thirty years ago, herbicides were often used on dense *Phragmites* stands in order to clean waterways or to induce the introduction of other plant species, which were more favored by wildlife. The site was also more suitable for game utilization as the penetrability for wildlife (and for hunters) was increased. An often used herbicide in *Phragmites* stands was Dalapon (Beck 1957).

Due to the greater knowledge at present with regard to the dangers caused by herbicides in food chains, these chemicals are no longer used.

5.1.2 Mechanical control

A combination of drainage and ploughing will prevent recolonization of a reed stand. *Phragmites* will decrease in vigor following drainage. Normal drainage will reduce the number of reed stems but will not completely eliminate them. Often the drainage process will allow competitors to invade the stand and in turn shade out young shoots, which will enhance control (Haslam 1968). The high evapotranspiration of *Phragmites* will actually speed the drying process (Haslam 1970c). Then the weakened *Phragmites* beds should be ploughed to a depth of 20 cm. This method is used in the newly reclaimed polders in The Netherlands in order to prepare the reed stands for agricultural use. For a noticeable control it is necessary to cut the horizontal rhizomes. The short rhizomes produced as an aftermath will produce short shoots that are easy to control (Haslam 1968).

Dredging is effective in control of *Phragmites* if the horizontal and vertical rhizomes are removed. If the dredging process leaves a water depth of over 1.5 m, recolonization will not take place unless accretion occurs (Haslam 1968).

Other mechanical and biological methods are more used as management procedures in order to create or maintain a reed stand as one likes it. They are not suitable to eliminate a reed stand completely.

5.2 Management

Management of a *Phragmites* is practiced for several reasons.

- To keep the density low as in drainage channels and waterways or in agricultural areas.
- To maintain an open reed stand as for natural conservation reasons or in recreation areas.
- To maintain a dense reed stand as for water purification or reed cultivation
- To keep diseases and insect infestation under control where *Phragmites* is used as bankprotection.

Several methods are available in order to manage a reed stand. Dredging and ploughing have been discussed before. Other methods are grazing, burning, cutting and mowing and active regulation of the water table.

5.2.1 Grazing

Cattle graze young buds and shoots. In combination with trampling which can destroy buds, they can suppress a reed stand. As discussed before waterfowl, in particular *Anser anser* can create and maintain a reed stand with an open character by grazing and is therefore these are preferred in nature conservation projects.

5.2.2 Burning

Fire can be applied at different moments of the growing season. Thompson and Shay (1985) tested the effects of fire on *Phragmites australis* in the Delta Marsh, Manitoba, Canada. They compared different burn treatments: burning in spring, summer, autumn and no fire at all. Standing crop was increased after fall and spring burns, as did the bud density. Burns in summer had no effect. Few damaged shoots were observed after the burns in spring and autumn. Higher total shoot density probably resulted from litter removal, as a thick litter mat reduces shoot density (Haslam 1972). In The Netherlands burning in the emergence period caused severe damage to the buds (Van der Toorn and Mook 1982). But burning in early spring, before bud emergence was favorable in insect control. The eggs of the moth *Archanara geminipunctata* remain on the shoots throughout the winter and after hatching in May, the larvae did not migrate. Also the moth *Rhizedra lutosa* can be controlled by burning, because its eggs overwinter near the shoot base. (Van der Toorn and Mook 1982, Mook and Van der Toorn 1982).

5.2.3 Mowing and cutting

Cutting and mowing are frequently applied in management of reed stands. Except for harvesting reasons (see: reed cultivation), mowing is applied to control the size and area of open water in fishponds (Husak 1978) and waterways.

Winter cutting is normal when the culms are used. This has a favorable effect on the development of the stand (Husak 1978), inducing an increase in stand density and homogeneity. Hansson and Graneli (1984) found an almost doubling of the shoot production. The shoots develop evenly and eggs of the moth *Archanara geminipunctata*, which hibernate on the shoots are removed (Van der Toorn and Mook 1978). Summer cutting does not effect underground biomass and the shoot diameter in the following spring. The reed regenerated by forming side shoots on the primary shoots, so the total number of shoots increased. The shoot biomass decreased, but if the value, reached in October is added to the amount removed in June, the result is not significantly different from the control.

Frequent cutting in one season lowered the biomass significantly (Mochnecka 1974c). Final standing crop after two successive mowings in mid June and mid July is only 3-4% of the

unmowed standing crop in mid October. When we add the 1st and 2nd harvest only 40% is reached. Total ash content, Si, Ca and K is not effected in stems due to mowing; but in leaves total ash, Si and Ca are reduced after mowing. K, P, and N are increased after mowing in the leaves and the P and N content also in the stems (Mochacka 1974).

Repeated winter harvest of reed and removal of dry reed culms during 4 successive winters caused an increased biomass during the growing season and this resulted in a lower phosphate concentration in the water column and sediment interstitial water (Hansson and Graneli 1984).

5.2.4 Active regulation of the water table

Productivity of a reed stand can be decreased by drainage. On the other hand flooding can increase the productivity. Reed cultivation is favored by flooding a plot by a mill. A layer of nutrient rich surface waters on the reed stand from April to July will suppress the introduction of other species (Brandsma 1982).

5.3 Nature conservation

Brandsma (1982) describes several aims of the management of reed stands with regard to nature conservation:

- The maintenance of the reed stand as community.
- The encouragement of the natural process of development into other communities. The maintenance and increasing of the internal variety of flora and fauna in a marshland in its entirety.

So in order to increase or maintain the internal variety of flora and fauna the reed stand should be open, which can be achieved by grazing by geese. At least locally, however, the formation of new succession stadia like peatbogs and woodland should be disturbed. A reed stand can also be used as buffer against the inflow of nutrient rich surface water to make succession possible into oligotrophic stadia.

In reed stands on peat soil the water level has to change as little as possible; it should not be flooded nor burned.

5.4 Reed cultivation

Often the reed grower wants another way of management of a reed stand than is preferred with regard to nature conservation. As described before the reed grower likes to flood the reed soil with nutrient rich water and to treat *Urtica*, *Rubus* and *Convolvulus* chemically (Brandsma 1982). Yearly harvest in winter promotes a dense stand the next year.

5.4.1 Reed harvest

The best time of the year to harvest reed for thatching and reed mat production is in winter from the end of December onwards. For the use as energy source winter harvesting has the disadvantage that only 50% of the biomass can be utilized. On the other hand winter harvesting has several advantages (Graneli 1984):

1. Destruction of rhizomes and dormant buds can be prevented if harvesting is done from ice or on frozen root mat
2. Only small amounts of nutrients are removed from the reed stands, as recycling to the rhizomes has been completed
3. Mechanical reed harvesting methods have been developed. The harvester can move easily and the ground can support a much heavier load than in summer.
4. The culms are harvested with a low water content and do not need drying before used as fuel
5. No serious environmental disturbance occurs.

Graneli (1984) describes several heavy harvesting machines, which can also cut the reed to smaller pieces. They all require an ice layer with a thickness of at least 40 cm. But with snow the harvester jams, the reed stems may crack down and harvesting fails (Loff 1987).

Chapter 6

References

- ALLEN, S.E. and W.H. PEARSALL, 1963. Leaf analysis and shoot production in *Phragmites*. *Oikos* 14:176-189.
- ALLENDER, B.C., 1984. Water quality improvement of pulp and paper mill effluents by aquatic plants. *Appita* 37:303-306.
- AMSHOFF, G.J.H. and J.Th. HENRARD, 1948. Flora of Suriname; edited by A. Pulle. Vol. I, Part I. Amsterdam, 1948.
- ANDERSON, B.W. and R.D. OHMART, 1985. Habitat use by clapper rails *Rallus longirostris yumanensis* in the lower Colorado River Valley USA. *Condor* 87:116-126.
- ANON., 1974. Artificial raising of giant pandas. *Acta Zool. Sin.* 20:148-153.
- APINIS, A.E. et al., 1972. Macrofungi colonizing submerged standing culms of *Phragmites communis* Trin. *Nova Hedwigia*. 23:473-480.
- AUCLAIR, A.N.D., 1979. Factors affecting tissue nutrient concentrations in a scirpus-equisetum wetland. *Ecology* 60:337-348.
- BAKKER, D. and D.T. BIEWINGA, 1957. Reeds in the Noordoostpolder. Van Zee tot Land, Nr 21, Directie van de Wieringermeer (Noordoostpolderwerken), Zwolle 55 pp.
- BANDUB, M.W., 1975. The effect of reeds on the waterchemistry of Gnadensee (Bodensee). *Arch. Hydrobiol.* 75:500-521.
- BAUDO, R. and P.G. VARINI, 1976. Copper, manganese and chromium concentrations of five macrophytes from the delta of river Toce (Northern Italy). *Mem. Ist. Ital. Idrobiol* 33:305-324.
- BAYLY, I.L. and T.A. O'NEILL, 1972. Seasonal ionic fluctuations

- in a *Phragmites communis* community. Can. J. Bot. 50:2103-2109.
- BECK, R., 1957. Herbicides increase gamefoods and edge in solid stands of *Phragmites*. Down to earth. 13:2-3.
- BECK, R.A., 1971. *Phragmites* control for urban, industrial and wildlife needs. Proc. 25th Northeastern Weed Science Meeting. 89-90.
- BENTON, A.H. and W.E. WERNER, Jr., 1958. Field biology and ecology. McGraw Hill. 564 pp.
- BEST, E.P.H., 1982. Growth modelling in aquatic macrophytes. In: Studies on Aquatic Vascular Plants pp. 102-111; eds: Symoens, J.J., S.S. Hooper and P. Compere. Roy. Bot. Soc. Belg., Brussels.
- BEST, E.P.H., M. ZIPPIN and J.H.A. DASSEN, 1981. Growth and production of *Phragmites australis* in Lake Vechten. Hydrobiol. Bull. 15:165-173.
- BEST, E.P.H., M. ZIPPIN and J.H.A. DASSEN, 1982. Studies on the decomposition of *Phragmites australis* leaves under laboratory conditions. Hydrobiol. Bull. 16:21-34.
- BIBBY, C.J., and J. LUNN, 1982. Conservation of reed beds and their avifauna in England and Wales, UK. Biol. Cons. 23:167-186.
- BJORK, S., 1967. Ecologic investigations of *Phragmites communis*. Folia Limnologia Scandinavica, No 14. Lund 247 pp.
- BJORK, S. and W. GRANELL, 1978. Energy reeds and the environment. Ambio 7:150-156.
- BOLEN, E.G., 1964. Plant ecology of spring-fed salt marshes in western Utah. Ecol. Monographs 34:143-166.
- BONHAM, A.J., 1983. The management of wave spending vegetation as bank protection against boat wash. Landscape Plann. 10:15-30.
- BOORMAN, L.A. and R.M. FULLER, 1981. The changing status of a reedswamp in the Norfolk Broads. J. Appl. Ecol. 18:241-269.
- BORNKAMM, R. and F. RAGHI-ATRI, 1986. Über die Wirkung unterschiedlicher Gaben von Stickstoff und Phosphor auf die Entwicklung von *Phragmites australis* (Cav.) Trin. ex Steudel. Arch. Hydrobiol. 105:423-441.
- BORDWIEC, E., 1975. Food of the coot (*Fulica atra* L.) in

- different phenological periods. Pol. Arch. Hydrobiol 22:157-166.
- BRANDSMA, M., 1982. Rietteelt en natuurwetenschappelijk beheer. Vakblad voor biologen 20:403.
- BRIX, H., 1986. Treatment of wastewater in the rhizosphere of wetland plants - The root-zone-method. Botanical Inst. University of Aarhus, Denmark.
- BURBRIDGE, N.T., 1966, 1968, 1970. Australian grasses. Vol. 1, 2 and 3. Sydney, 1966, 1968, 1970.
- BURGER, J. and L.M. MILLER., 1977. Colony and nest site selection in white-faced and glossy ibises. The Auk 94:664-676.
- BURGER, J. and J. SHISLER, 1980. Colony and nest site selection in laughing gulls, *Larus atricilla* in response to tidal flooding. Condor 82:251-258.
- BURIAN, E., 1971. Primary production, carbon dioxide exchange and transpiration in *Phragmites communis* Trin. on the Lake Neusiedlersee, Austria. Hydrobiologia 12:203-218.
- BURIAN, E., 1973. *Phragmites communis* Trin. im Rohricht des Neusiedler Sees. Wachstum, Produktion und Wasserverbrauch. Ökosystemforschung. Herausgegeben von H. Ellenberg. Springer Verlag. Berlin - Heidelberg - New York.
- BUTTERY, B.R. and J.M. LAMBERT, 1965. Competition between *Glyceria maxima* and *Phragmites communis* in the region of Birmingham Broad. I. The competition mechanism. J. Ecol. 53:163-181.
- CABRERA, A.L., 1953. Manuel de la Flora de Los Alrededores de Buenos Aires. Buenos Aires, 1953.
- CRUEMAN, V.J., 1960. Salt marshes and salt deserts of the world. L. Hill, London. 392 pp.
- CHINGIZANI, G., 1969. Normal contents and accumulations of copper in *Phragmites communis* as a response to those in the sediments of 6 Italian lakes. Mem Ist Ital Idrobiol 25: 81-95.
- CLAYTON, W.D., 1967. Studies in the Gramineae: 14. Kew Bull. 21:111-117.
- CLAYTON, W.D., 1968. The correct name of the common reed. Taxon 17:168-169.

- CLAYTON, W.D., 1970. Flora of tropical East Africa; edited by E. Milne-Redhead and R.M. Polhill. Part I (Gramineae). London, 1970.
- CONERT, H.J., 1961. Die Systematik und Anatomie der Arundineae. Weinheim, 1961.
- COWLING, S.J. and K.W. LOWE, 1981. Studies of ibises in Victoria, I: Records of breeding since 1955. The Emu 81:33-39.
- DANIELS, R.E., 1975. Observations on the performance of *Narthecium ossifragum* (L.) Huds. and *Phragmites communis* Trin. J. Ecol. 63:965-977.
- DE LA CRUZ, A.A., 1978. The production of pulp from marsh grass. Econ. Bot. 32:46-50.
- DE JONG, J., T. KOK and A.H. KORIDON, 1977. The purification of sewage with the aid of ponds containing bullrushes or reeds in the Netherlands. Rapport 1977-7 BbW. Lelystad, Netherlands: Rijksdienst voor de IJsselmeerpolders.
- DURSKA, B., 1970. Changes in the Reed (*Phragmites communis* Trin.) condition caused by diseases of fungal and animal origin. Pol. Arch. Hydrobiol. 17:373-396.
- DYKYJOVA, D. 1979. Selective uptake of mineral ions and their concentration factors in aquatic higher plants. Folia Geobot. Phytotax 14:267-325.
- DYKYJOVA, D., J.P. ONDOK and K. PRIBAN., 1970. Seasonal changes in productivity and vertical structure of reed-stands (*Phragmites communis* Trin.), Photosynthetica 4:280-287.
- DYKYJOVA, D. et al., 1973. Proposal for international comparative investigation of production by stands of reed (*Phragmites communis*). Folia Geobot. Phytotax. 8:435-442.
- DYKYJOVA, D. and J. KVET, 1978. Pond Littoral Ecosystems. Springer-Verlag, Berlin, Heidelberg, New York.
- EIFERT, V.S., 1959. River World. Dodd, Mead, N.Y. 271pp.
- ERRINGTON, P.L., 1941. Versatility in feeding and population maintenance of the musk rat. J. Wildl. Manage. 5:68-69.
- FINLAYSON, C.M. and A.J. CHICK, 1983. Testing the potential of aquatic plants to treat abattoir effluent. Water Res. 17:415-422.

- FLEMING, T.H., 1981. Winter roosting and feeding behaviour of pied wagtails *Motacilla alba* near Oxford, England. *Ibis* 123:463-476.
- FROMEL, R., 1980. Die Verbreitung im Schilf überwinternder Arthropoden im westlichen Bodensee und ihre Bedeutung für Vogel. *Die Vogelwarte* 30:218-254.
- GARDNER, C.A., 1952. *Flora of Western Australia*. Vol. I, part. Perth, 1952.
- GODWIN, H. and J.S. TURNER, 1933. Soil acidity in relation to vegetational succession in Galthorpe Broad, Norfolk. *J. Ecol.* 21:235-263.
- GORDON-GRAY, K.D. and C.J. WARD, 1971. A contribution to knowledge of *Phragmites* (Gramineae) in South Africa, with particular reference to Natal populations. *Jl. S. Afr. Bot.* 37:1-30.
- GORHAM, E. and W.H. PEARSALL, 1956a. Acidity, specific conductivity and calcium content of some bog and fen waters in northern Britain. *J. Ecol.* 44:129-141.
- GORENFLOT, R., et al., 1972. The polyploid complex of *Phragmites communis* Trin. *C.R. Hebd. Seances Acad. Sci. Ser. D. Sci. Nat. (Paris)* 274:1501-1504.
- GRANELI, W., 1984. Reed *Phragmites australis* (Cav.) Trin. ex Steudel as an energy source in Sweden. *Biomass* 4:183-208.
- GUNNISON, D., 1978. Mineral cycling in salt marsh-estuarine ecosystems. Technical report D-78-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, USA. 2pp.
- GUSTAFSSON, A. and M. SIMAK, 1963. X-ray photography and seed sterility in *Phragmites communis* Trin. *Hereditas* 49:442-450.
- HANSSON, L.-A. and W. GRANELI, 1984. Effects of winterharvest on water and sediment chemistry in a stand of reed *Phragmites australis*. *Hydrobiologia* 112:131-136.
- HARRADINE, A.R., 1982. Effect of salinity on germination and growth of *Pennisetum macrourum* in Southern Tasmania. *J. Appl. Ecol.* 19:273-282.
- HASLAM, S.M., 1968. The biology of reed (*Phragmites communis*) in relation to its control. *Proc. 9th Br. Weed Control Conf.* 192-197.

- HASLAM, S.M., 1969b. The development and emergence of buds in *Phragmites communis* Trin. Ann. Bot. N.S. 33:289-301.
- HASLAM, S.M., 1969c. The development of shoots in *Phragmites communis* Trin. Ann. Bot. N.S. 33:695-709.
- HASLAM, S.M., 1970a. The development of the annual population in *Phragmites communis* Trin. Ann. Bot. N.S. 34:571-591.
- HASLAM, S.M., 1970b. The performance of *Phragmites communis* Trin. Ann. Bot. N.S. 34:147-158.
- HASLAM, S.M., 1970c. The performance of *Phragmites communis* Trin. in relation to water-supply. Ann. Bot. N.S. 34:867-877.
- HASLAM, S.M., 1971a. Community regulation in *Phragmites communis* Trin. I. Monodominant stands. J. Ecol. 59:65-73.
- HASLAM, S.M., 1971b. Community regulation in *Phragmites communis* Trin. II. Mixed stands. J. Ecol. 59:75-88.
- HASLAM, S.M., 1971c. The development and establishment of young plants of *Phragmites communis* Trin. Ann. Bot. N.S. 35:1059-1072.
- HASLAM, S.M., 1972. *Phragmites communis* Trin. Biol. Flora Brit. Isles. J. Ecol. 60:585-610.
- HASLAM, S.M., 1973. Some aspects of the life history and autecology of *Phragmites communis* Trin. A Revies. Pol. Arch. Hydrobiol. 20:79-100.
- HASLAM, S.M., 1975. The performance of *Phragmites communis* Trin. in relation to temperature. Ann. Bot. 39:881-889.
- HERBST, G. and S.R. REICE, 1982. Comparative leaf litter decomposition in temporary and permanent streams in semi-arid regions of Israel. J. Arid Environments 5:305-318.
- HITCHCOCK, A.S., 1913. Mexican grasses in the U.S. Nat. Herbarium. Contrib. U.S. Nat. Herb. 17, part 3.
- HITCHCOCK, A.S., 1927. The grasses of Ecuador, Peru and Bolivia. Contrib. U.S. Nat. Herb. 24, part 8.
- HITCHCOCK, A.S., 1930. The grasses of Central America. Contrib. U.S. Nat. Herb. 24, part 9.
- HITCHCOCK, A.S., 1936. Manual of the grasses of the West Indies. Washington, 1936. (U.S. Dep. of Agricult. Miscell. Publ.;

no.243).

- HITCHCOCK, A.S., 1950. Manual of the grasses of the United States. 2nd Ed. U.S. Govt. Print. Off. Washington, D.C. 1051 pp.
- HO, Y.B., 1979. Shoot development and production studies of *Phragmites australis* (Can.) Trin. ex Steudel in Scottish Lochs. *Hydrobiologia* 64:215-222.
- HO, Y.B., 1981. Mineral composition of *Phragmites australis* in Scottish lochs as related to eutrophication. 1: Seasonal changes in organs. *Hydrobiologia* 85:227-237.
- HOPKINSON, C.S., J.G. GOSSELINK and R.T. PARONDO, 1978. Aboveground production of seven marsh plant species in coastal Louisiana. *Ecology* 59:760-769.
- HUBBARD, C.E., 1968. Grasses, a guide to their structure, identification, uses, and distribution in the British isles. 2nd Edition. Penguin Books Ltd.
- HUDEC, K., 1973a. Die nahrung der Graugans, *Anser anser*, in Sudmahren. *Zool. Listy* 22:41-58.
- HUDEC, K., 1973b. Occurrence of food of the greylag goose (*Anser anser*) at the Nyset fishpond. In: Littoral of the Nesyt Fishpond, edited by J. Kvet, Academia, Praha. pp. 121-124.
- HULTEN, E., 1962. The circumpolar plants I. Vascular cryptogams, Conifers, Monocotyledons. Stockholm, 1962.
- HUSACK, S., 1978. Control of reed and reedmace stands by cutting. In: Pond littoral ecosystems, edited by D. Dykyjova & J. Kvet, Springer Verlag, Berlin. pp. 404-408.
- HURLIMANN, H., 1951. Zur Lebensgeschichte des Schilfs and der Ufern der Schweizer Seen. *Beitr. geobot. Landesaufn. Schweiz* 30. 232 pp.
- IHSE, M.S. and W. GRANELI., 1985. Estimation of reed (*Phragmites australis*) biomass through spectral reflectance measurements. *Biomass* 8:59-79.
- IMHOF, G., 1973. Aspects energy flow by different food chains in a reed bed. A review. *Pol. Arch. Hydrobiol.* 20:65-168.
- INGRAM, H.A.P., A.M. BARCLAY, A.M. COUPAR, J.G. GLOVER, B.M. LYNCH and J.I. SPRENT., 1980. *Phragmites* performance in reed beds in the Tay estuary. *Proceed. of the Roy. Soc of*

Edinburgh. 78B:89-107.

- JOANAN, T., 1969. Nesting ecology of alligators in Louisiana. 23rd Ann. Conf. Southeastern Assoc. of Game and Fish Comm.
- KAMIO, A., 1982. Studies on the drying of marshy and heavy clay soil ground by means of vegetation on the process of polder land drainage and structural changes of *Phragmites communis* community in the Hachirogata central polder Akita prefecture, Japan. JPN J. Ecol. 32:357-364.
- KARZHAVINA, L.A., 1975. State and prospects of the development of reed raw material sources in the Volga Delta. the Zuid Flevoland area. Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afd. Natuurkunde, Tweede Reeks 67:120-126.
- KAUL, S., 1984. Biomass and mineral composition of aquatic macrophytes in the Hygam wetland, Kashmir with reference to substrate nutrients. Acta hydrochim. et hydrobiol. 12:81-91.
- KAUPPI, P., J. SELKAINAHO and P. PUTTONEN, 1983. A method for estimating above-ground biomass in *Phragmites* stands. Ann. Bot. Fennici 20:51-55.
- KHASHES, T.M. and V.I. BOBRO, 1974. Diurnal and seasonal transpiration dynamics in *Phragmites communis* Trin. UKR Bot. Zh. 28:521-524.
- KLOTZLI, F., 1971. Biogenous influence on aquatic macrophytes, especially *Phragmites communis*. Hydrobiologia. 12:107-111.
- KOVACS, M., 1982. Chemical composition of the lesser reedmace (*Typha angustifolia* L.) in lake Balaton. Acta Bot. Acad. Sci. Hung. 28:297-307.
- KOVACS, M., I. PRECSENYI and J. PODANI, 1978. Anhaufung von elementen im balatoner schilfrohr (*Phragmites communis*). Acta Botanica Academiae Scientiarum Hungaricae. 24:99-111.
- KRASOVSKII, L.I. and V.A. CHASHCKUKHIN, 1974. Oxygen regime of the rootstocks of common reed. Fiziol. Rast. 21:315-319.
- KROLIKOWSKA, J., 1971. Transpiration of reed (*Phragmites communis* Trin.). Pol. Arch. Hydrobiol. 18:347-358.
- KUFEL, I., 1978. Seasonal changes of Pb, Cu, Mo and Co in above-ground parts of *Phragmites australis* Trin. ex Steudel and *Typha angustifolia* L. Bull. Acad. Pol. Sci. 26:765-770.

- KUFEL, I. and L. KUFEL, 1981. Chemical composition of reed (*Phragmites australis* Trin. ex Steudel) in relation to the substratum. Bull. Acad. Pol. Sci. Ser. Sci. Biol. 28:563-568.
- KUITERS, A.T., 1987. Phenolic acids and plant growth in forest ecosystems. Thesis, Vrije Universiteit, Amsterdam.
- KVET, J. and K. HUDEC, 1971. Effects of grazing by grey-lag geese on reedswamp plant communities. Hydrobiologia 12:351-359.
- KVET, J., 1973a. Mineral nutrients in shoots of reed (*Phragmites communis* Trin.). Pol. Arch. Hydrobiol. 20:137-146.
- LAMBERT, J.M., 1946. The distribution and status of *Glyceria maxima* (Hartm.) in the region of Surlingham and Rockland Broads, Norfolk. J. Ecol. 33:230-267.
- LANNING, F.C. and L.N. ELEUTERIUS, 1985. Silica and ash in tissues of some plants growing in the coastal area of Mississippi USA. Ann. of Bot. 56:157-172.
- LARSEN, V.J., 1983. The significance of atmospheric deposition of heavy metals in 4 Danish Lakes. Sci. Total Environ. 30:111-128.
- LARSEN, V.J. and H. SCHIERUP, 1981. Macrophyte cycling of zinc, copper, lead and cadmium in the littoral zone of a polluted and non-polluted lake. II Seasonal changes in heavy metal content of aboveground biomass and decomposing leaves of *Phragmites australis*. Aquat. Bot. 11:211-230.
- LAUNERT, E., 1970. Prodomus einer Flora von Südwestafrika; herausgegeben von H. Merxmüller. 160 (Gramineae). München, 1970.
- LEE, C.R. et al., 1976. Feasibility of the functional use of vegetation of filter, dewater, and remove contaminants from dredged material. Technical Report D-76-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, USA.
- LOFF, Y., 1987. Winter, zomer: er is altijd werk in De Wieden. Natuurbehoud, Vereniging tot Behoud van Natuurmonumenten in Nederland. 18 (1):5.
- LUTHER, H., 1983. On life forms and aboveground and underground biomass of aquatic macrophytes. Acta Bot. Fenn. 123:1-23.
- LYNCH, J.J., T. O'NEILL and D.W. LAY. 1974. Management and significance of damage by geese and muskrats to gulf coast marshes. J. Wildl. Manage. 11:50-76.

- MANTLE, P.G., 1969. Studies on *Claviceps purpurea* (Fr.) Tul. parasitic on *Phragmites communis* Trin. Ann. Appl. Biol. 63:425-434.
- MARTIN, A.C., 1953. Improvement of duck marshes by weed control. U.S. Fish and Wildlife Circular 19. U.S. GPO. Washington, D.C.
- MEREZHKO, A.I. and T.I. SHOKOD'KO, 1978. Characteristics of DDT uptake by higher aquatic plants. *Gidrobiol Zh* 14:84-91.
- MEULEMANS, J.T., 1982. Seizoensgebonden veranderingen in bovengrondse biomassa van riet. Vakblad voor biologen 20:404-405.
- MILLER, R.S., 1967. Pattern and process in competition. Adv. Ecol. Res. 4:56-67.
- MISRA, R.D., 1938. Edaphic factors in the distribution of aquatic plants in the English Lakes. J. Ecol. 26:411-451.
- MOCHNAŁA-LAWACZ, H., 1974a. Seasonal changes of *Phragmites communis*. I. Growth, morphometrics, density and biomass. Pol. Arch. Hydrobiol., 21:355-368.
- MOCHNAŁA-LAWACZ, H., 1974c. The effects of mowing on the dynamics of quantity, biomass and mineral contents of reed (*Phragmites communis*). Pol. Arch. Hydrobiol. 21:381-386.
- MOOF, J.H., 1971. Influence of environment on some insects attacking common reed (*Phragmites communis* Trin.) *Hydrobiologia* 12:305-312.
- MOOF, J.H., 1982. Populatie-ecologisch onderzoek aan riet. Vakblad voor biologen. 20:400-402.
- MOOF, J.H. and J. VAN DER TOORN, 1982. The influence of environmental factors and the management on stands of *Phragmites australis*. II. Effect on yield and its relationships with shoot density. J. Appl. Ecol. 19:501-517.
- MOOF, J.H. and J. VAN DER TOORN, 1985. Delayed response of common reed (*Phragmites australis*) to herbivory as a cause of cyclic fluctuations in the density of the moth *Archana geminipuncta*. *Oikos* 44:142-148.
- NEWBOULD, P.J. and E. GORHAM, 1956. Acidity and specific conductivity measurements in some plant communities of the New Forest valley bogs. J. Ecol. 44:118-128.
- ODUM, W.E. and J.E. DRIFMEYER, 1978. Sorption of pollutants by

- plant detritus: a review. Environ. Health Perspectives. 27:133-137.
- ULSCHLEGEL, H., 1984. The effects of removing reeds in a pond area in the brooding stock of the reed warbler *Acrocephalus scirpaceus*. Beitr. z. Vogelk. 30:178-184.
- UNDOK, J.P., 1973a. Photosynthetically active radiation in a stand of *Phragmites communis* Trin.: II. Model of light extension in the stand. Photosynthetica (Prague) 7:50-57.
- UNDOK, J.P., 1973b. Photosynthetically active radiation in a stand of *Phragmites communis* Trin.: III. Distribution of irradiance on sunlit foliage area. Photosynthetica (Prague) 7:311-319.
- ONEILL, T., 1949. The muskrat in the Louisiana coastal marshes. Louisiana Department Wildlife and Fisheries, New Orleans 152 pp.
- OSTENFELD, C.H. and J. GRONTVED, 1934. The flora of Iceland and the Faeroes. Copenhagen, 1934.
- FAZOUK, J., 1973. The density of stomata in leaves of different ecotypes of *Phragmites communis*. Folia Geobot. Phytotax. 8:15-21.
- PHILLIPS, S.F., 1976. The relationship between evapotranspiration by *Phragmites communis* Trin. and water table fluctuations in the Delta Marsh, Manitoba. Diss. Abstr. Int'l. B. The Sciences and Engr. Vol. 37 (6).
- FOLUNIN, N.V.C., 1984. The decomposition of emergent macrophytes in fresh water. Adv. Ecol. Res. 14:115-166.
- FOORTER, E.P.K., 1982. Ganzen en riet in de Oostvaardersplassen. Vakblad voor biologen. 20:398-399.
- RADOUX, M., 1982. Etude comparee des capacites epuratrices d'un lagunage et d'un marais artificiel miniatures recevant la meme eau usee en zone rurale. Studies on aquatic vascular plants, edited by J.J. Symoens, S.S. Hooper and P. Compere. Roy. Bot. Soc. Belg., Brussels pp. 346-352.
- RAGHI-ATRI, F. and R. BORNKAMM, 1980. Uber Halmfestigkeit von Schilf (*Phragmites australis* [Cav.] Trin. ex Steudel) bei unterschiedlicher Nahrstoffversorgung. Arch. Hydrobiol. 90:90-105.
- RAICU, P., S. STRAICU, V. STOIAN and J. ROMAN, 1972. The

- Phragmites communis* Trin. chromosome complement in the Danube Delta. *Hydrobiol.* 39:83-89.
- RANWELL, D.S., E.F.C. BIRD, J.C.E. HUBBARD and R.E. STEBBENS, 1964. Tidal submergence and chlorinity at Poole Harbour. *J. Ecol.* 52:627-642.
- REICE, S.R. and G. HERBST, 1982. The role of salinity in decomposition of leaves of *Phragmites australis* in desert streams. *J. Arid Environments* 5:361-368.
- REININK, K. and J. VAN DER TOORN, 1976. Effect of changes in water table on the vegetation development of reedbeds in the Zuid Flevoland area. *Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Afd. Natuurkunde, Tweede Reeks*, 67:120-126.
- REZK, M.R. and T.Y. EDANY, 1979. Comparative responses of two reed sp. to water table levels. *Egypt. J. Bot.* 22:157-172.
- RICCIUTI, E.R. 1983. The all too common, common reed. *Aubudon* 85:65-66.
- ROMAN, C.T. and F.C. DAIBER, 1984. Aboveground and belowground primary production dynamics of two Delaware Bay USA tidal marshes. *Bull. Torrey Bot. Club* 111:34-41.
- ROMAN, C.T., W.A. NIERING and R. SCOTT WARREN, 1984. Salt marsh vegetation change in response to tidal restriction. *Environ. Manage.* 8:141-150.
- RYCHNOVSKA, M. and P. SMID, 1973. Preliminary evaluation of transpiration in two *Phragmites* stands. Ecosystem study on wetland bioma in Czechoslovakia. *Czechosl. IBP/PT-PP Report No. 3* (Ed. S. Hejny) pp. 111-119, Trebon.
- SARFKA, J., M.L. HATTULA, J. JANATUINEN and J. PAASIVIRTA, 1978. Chlorinated hydrocarbons and mercury in aquatic vascular plants of lake Paljanne, Finland. *Bull Environm. Contam. Toxicol* 20:361-368.
- SCHIERUP, H. and V.J. LARSEN, 1981. Macrophyte cycling of zinc, copper, lead and cadmium in the littoral zone of a polluted and non-polluted lake. I Availability, uptake and translocation of heavy metals in *Phragmites australis* (Cav.) Trin. *Aquat. Bot.* 11:197-210.
- SCHLOTT, G. and G. MALICKY, 1984. Biomass and Phosphorus content of the macrophytes of the northeast bay of the Lunzer untersee Austria in relation to nutrient-rich inflows and to the

- sediment. Arch. Hydrobiol. 101:265-277.
- SEIDEL, K., 1971. Macrophytes as functional elements in the environment of man. Hydrobiologica 12:121-130.
- SELF, C.A., R.H. CHABRECK and T. JOANEN, 1974. Food preferences of deer in Louisiana coastal marshes. 28th Ann. Conf. Southeastern Assoc. of Game and Fish Comm.
- SHOKOD'KO, T.I., A.I. MEREZHKO and A.H. LYASHENKO, 1978. Effect of DDT and BHC on assimilation and outflow of carbon-14 in *Phragmites communis*. Gidrobiol Zh. 14:105-109.
- SIEGHARDT, H., 1973. Strahlungsnutzung von *Phragmites communis*. Ökosystem forschung. Herausgegeben von H. Ellenberg. Springer Verlag. Berlin - Heidelberg - New York.
- SIEGHARDT, H., O. HAMMER and G. TEUSCHL, 1984. Das Schilfrohr (*Phragmites australis* (Cav.) Schilfgürtels am Neusiedlersee. BFB-Bericht 51:37-47.
- SIEGHARDT, H. and R. MAIER, 1985. Produktionsbiologische Untersuchungen an *Phragmites*-Beständen im geschlossenen Schilfgürtel des Neusiedlersees. Forschungsbericht Neusiedlersee 1981-1984 (AGN9. Wiss. Arb. Burgenland. Sonderband 72:190-221.
- SMID, P., 1975. Evaporation from a reedswamp. J. Ecol. 60:299-309.
- STANT, M., 1953. Variation in reed structure in relation to thatching. Kew Bull. 2:231-239.
- SZCZEPANSKA, W., 1971. Allelopathy among the aquatic plants. Pol. Arch. Hydrobiol. 18:17-30.
- SZCZEPANSKA, W., 1973. Production of helophytes in different types of lakes. Pol. Arch. Hydrobiol. 20:51-57.
- SZCZEPANSKA, W., 1977a. Development of *Phragmites communis* Trin. Depending on the amount of the available soil. Pol. Arch. Hydrobiol. 24:311-318.
- SZCZEPANSKA, W., 1977b. Interactions of *Phragmites communis* Trin. and *Carex hudsonii* Bennet. Ekol. Pol. 25:431-436.
- SZCZEPANSKA, W., 1977c. The effect of remains of Helophytes on the growth of *Phragmites communis* Trin. and *Typha latifolia* L. Ekol. Pol. 25:437-445.
- SZCZEPANSKA, W. and A. SZCZEPANSKI, 1973. Emergent macrophytes

- and their role in wetland ecosystems. Pol. Arch. Hydrobiol. 20:41-50.
- SZCZEPANSKA, W. and A. SZCZEPANSKI, 1982. Interactions between *Phragmites australis* and *Typha latifolia*. Ekol. Pol. 30:165-186.
- SZCZEPANSKI, A.J., 1978. Ecology of macrophytes in wetlands. Pol. Ecol. Studies 4:45-94.
- TALIGDOLA, T.K., A.E. APINIS and C.G.C. CHESTERS, 1972. Microfungi colonizing collapsed aerial parts of *Phragmites communis* Trin. in water. Nova Hedwigia 23:465-472.
- TAYLOR, G.J. and A.A. CROWDER, 1983. Uptake and accumulation of heavy metals by *Typha latifolia* in wetlands of the Sudbury, Ontario region. Can. J. Bot. 61:63-73.
- TAYLOR, G.J. and A.A. CROWDER, 1983. Uptake and accumulation of copper, nickel and iron by *Typha latifolia* grown in solution culture. Can. J. Bot. 61:1825-1830.
- THOMPSON, D.J. and J.M. SHAY, 1985. The effects of fire on *Phragmites australis* in the Delta marsh, Manitoba. Can. J. Bot. 63:1864-1869.
- TOWNROW, J.E.S., 1969. A species list of and keys to the grasses in Tasmania. pap. Proc. R. Soc. Tasm.; 103:69-96.
- TUSCHL, P., 1970. Die Transpiration von *Phragmites communis* Trin. in Geschlossenen bestand des Neusiedler Sees. Wiss. Arb. Burgenld. 44:126-186. TUXEN, R. (ed.), 1982. Phragmitetea. Bibliographia Phytosociologica Syntaxonomica. Vol. 36. J. Cramer, Vaduz.
- ULEHLOVA, B., S. HUSAK and J. DVORAK, 1973. Mineral cycles in reed stands of Nesyt Fishpond in southern Moravia. Pol. Arch. Hydrobiol. 20:121-129.
- ULRICH, K.E. and T.M. BURTON, 1985. The effects of nitrate, phosphate and potassium fertilization on growth and nutrient uptake patterns of *Phragmites australis* (Cav.) Trin. ex Steudel. Aquat. Bot. 21:53-62.
- VAN ACHT, W.N.M. and J.T.M. SESSINK, 1982. Natuurlijke oeverbescherming. Vakblad voor biologen 20:406-409.
- VAN DER LINDEN, M.J.H.A., 1980. Nitrogen economy of reed vegetation in the Zuidelijk Flevoland Polder. I. Distribution of nitrogen among shoots and rhizomes during the growing season

- and loss of nitrogen due to fire management. Acta Oecol., Oecol. plant. 1:219-230.
- VAN DER TOORN, J., 1971. Investigations on the ecological differentiation of *Phragmites communis* Trin. in the Netherlands. Hydrobiologia 12:97-106.
- VAN DER TOORN, J., 1972. Variability of *Phragmites australis* (Cav.) Trin. ex. Steudel in relation to the environment. Van zee tot land 48:122 pp.
- VAN DER TOORN, J., 1979a. Pot experiment to test a possible selection occurring in a differently treated reed vegetation. Verh. Kon. Akad. Wetenschappen, Afd. Natuurkunde, Tweede Reeks, 73:332-335.
- VAN DER TOORN, J., 1982. Invloed van beschadigingen op de groei van riet en vegetatie ontwikkeling in de IJsselmeerpolders. Vakblad voor biologen 20:394-397.
- VAN DER TOORN, J. and K. REININK, 1978. Experiments on the establishment of plant species in a reed field. Verh. Kon. Akad. Wetenschappen, Afd. Natuurkunde, Tweede Reeks, 71:292-295.
- VAN DER TOORN, J. and J.H. MOOK, 1982. The influence of environmental factors and management on stands of *Phragmites australis* I. Effects of burning, frost and insect damage on shoot density and shoot size. J. Appl. Ecol. 19:477-499.
- VAN DER TOORN, J., J.H. MOOK and K. REININK, 1983. Influence of insect damage and management on succession in reed stands (*Phragmites australis*). Proc. Int. Symp. Aquat. Macrophytes, Nijmegen, The Netherlands, 18-23 September 1983, 225-229.
- VEBER, K., 1978. Propagation, Cultivation and Exploitation of Common Reed in Czechoslovakia. In: Pond littoral ecosystems, edited by D. Dykyjova and J. Kvet. Springer Verlag, Berlin, Heidelberg, New York. pp 416-423.
- VOSTOKOVA, E.A., 1975. Ecologic and hydrogeologic role of sheet grass communities in the sand deserts of the northern Aral Reion. Ekologiya 6:83-89.
- WASEL, Y. and Y. RECHAW, 1971. Ecotypic differentiation in *Phragmites communis* Trin. Hydrobiologia 12:259-266.
- WALLENTINUS, H.G., et al., 1973. The reed *Phragmites communis* Trin., in the Brunnsviken. Sven. Bot. Tidskr. 67:81-96.

- WALTER, J.M. and E.R. WHIMMOB, 1980. Ecology of *Phragmites* communities. I. Photosynthesis of a single shoot. *Ecology* 61:461-474.
- WERNER, J.E., 1980. Flood plain vegetation of the Rhine delta of the Valle. *Ecot. Monogr.* 50:49-56.
- WILL, H., 1983. Der Bergrübler. *Beitr. z. Veget. u. Landschaftsk. nördlichen Mitteleuropa*. Vogelweil 1:179-181.
- WOLVERTON, B.O., 1982. Hybrid waste water treatment using aerobic and anaerobic microorganisms and reed (*Phragmites*). *Ecology* 63:212-220.
- WOLVERTON, B.O. and R.C. McDOUGALL, 1983. Evaluation of criteria and cost estimations for hybrid treatment systems (*Phragmites* communities) wastewater treatment. *Technical memorandum TM-8468*.
- WOLVERTON, B.O., R.C. McDOUGALL, W.K. LARSEN, and J. HARRIS, 1983. Hybrid treatment systems using reeds and higher plants for waste water treatment. *Water Res.* 17:236-242.
- YABOVSKI, E.B. and H.I. BERTZKE, 1983. Dynamics of nitrogenous compounds in a number of higher plant species and dynamics of their content during vegetation. *Vegetatio* 51:81-84.
- YAMASHITA, S., 1981. Effects of water level on the growth of the rhizomes of three hydrophytes. *Jap. J. Ecol.* 31:27-34.
- YAMASHITA, S., 1984. Role of plant aeration in the growth of *Phragmites latifolia* and *Phragmites australis*. *Aquatic Bot.* 28:1-10.
- YIM, Y., 1975. Dry matter production and leaf area index of a *Phragmites* community in central Korea. *Korean J. Bot.* 18:87-93.
- ZONNEVELD, I.S., 1959. A study of soil and vegetation of a freshwater tidal area. Wageningen. (Versl. Landbouwk. Onderz.: no. 65.20).

Appendix A

Literature not referenced

- CHEN, Y. and J. CHEN, 1985. The ecology and population dynamics of *Scirpus tibeticus* at a northwest marsh. *J. Ecol.* 73:87-92.
- CHEN, Y. and J. CHEN, 1986. The plant communities as indicators of environmental change in a saline marsh in Dagestan (USSR). *Ekologiya i Prirodnoye Raznoobrazie* 1:1-10.
- CHEN, Y. and J. CHEN, 1985. The potential of *Scirpus tibeticus* for the treatment of waste waters in the coastal zone. The technology transfer in water pollution control in developing areas. Ciskei, South Africa.
- CHEN, Y. and J. CHEN, 1980. The significance of reed swamps in the Tia Estuary. *Proceed. of the Roy. Soc. Edinb.* 80:511-513.
- CHEN, Y. and J. CHEN, 1976. Primary productivity in shallow water lake with special reference to reed swamp. *Oikos* 27:243-250.
- CHEN, Y. and J. CHEN, 1978. Effects of nutrient level on the distribution of *Phragmites communis*. *Arch. Hydrobiol.* 94:103-104.
- CHEN, Y. and J. CHEN, 1981. Oxygen and nitrate respiration in a reed swamp sediment from a eutrophic lake. *Holarctic Ecol.* 4: 35-42.
- CHEN, Y. and J. CHEN, 1982. Nitrogen cycling and microbial decomposition in sediments with *Phragmites australis*, *Poaceae*. *Hydrobiol. Bull.* 16:11-20.
- ANDREWS, N.J. and D.C. PRATT, 1981. Wetland energy crops: the productive potential of *Typha* spp., *Phragmites communis* and *Phalaris arundinacea* in Minnesota. *Energy from Biomass*, 1st

AD-A178 333

BIOLOGY MANAGEMENT AND UTILIZATION OF COMMON REED
PHARAGMITES AUSTRALIS (U) VRIJE UNIV AMSTERDAM
(NETHERLANDS) DEPT OF ECOLOGY AND ECOTOX..
M U WERFF ET AL. FEB 87 DAJA45-86-M-0482

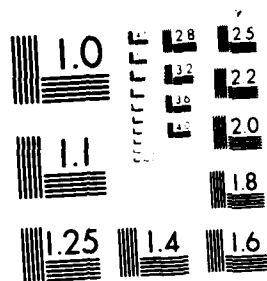
2/2

UNCLASSIFIED

F/G 6/6

NL

END
JAN
1987



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

E.C. Conference. pp. 75-82.

ANON. 1975. "Organic" treatment. Environmental Action. March 29:15.

ANON. 1984. Reed system at Hightstown, N.J. Biocycle 84:39.

BAKKER, D., 1957. Preliminary results of experiments with Common reed, Reed grass and Bulrush performed in 1956 at "the spijk". Flevoverichten B Nr 3, Directie van de Wieringermeer (Noordoostpolderwerken), Zwolle, 6pp.

BAKKER, D., 1957. The vegetation of Oostelijk Flevoland in 1957. Internal report, Directie van de Wieringermeer (Noordoostpolderwerken), Zwolle, 12 pp.

BALASHOV, L.S., 1972. Peat floating in the reservoir of the Kiev Hydroelectric Station and its role in water contamination. UKR Bot. Zh. 29:49-54.

BALL, E.W., 1958. Results in applying dalapon by aircraft to pest plants in waterfowl areas of the Southwest. Down to earth 14:11-14.

BARCLAY, A.M., H.A.P. Ingram, B.M. LYNCH, J.I. SPRENT and R.L. MCMILLAN, 1976. The performance of reeds in the Firth of Tay 1975. Unpublished report to Nature Conservancy Council, Edinburgh. Dundee University.

BECK, R.A. and J.H. STEENIS, 1964. *Phragmites* control in Delaware. Proc. Northeast Weed Control Conference. New York, NY. 504-506.

BENEMAN, J.R., 1981. Energy from fresh and brackish water aquatic plants. J. Acs Symp. Ser. 144:99-121.

BERGGREN, H., 1975. Pahlava Mordab a threatened Iranian bird paradise. Fauna Flora (Stockh) 70:164-170.

BERNATOWICZ, S., 1965. Effects of mowing on the occurrence of macrophytes in the Dgal Maly lake. Acta Hydrobiol 7:71-81.

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

BITTMAN, E., 1953. Das Schilff (*Phragmites communis* Trin.) und seine Verwendung in Wasserbau. Angew. Pflanzensoziologie 7:1-47

BJORK, S., 1972a. Swedish lake restoration program gets results. Ambio 1:153-165.

- BJORK, S., 1972b. Bringing sick lakes back to health. Teknisk tidskrift. 11:112-118.
- BJORK, S., 1974. European lake rehabilitation activities. Plenary lecture, conference on lake protection and management. Madison, Wisconsin.
- BJORNDAL, G., 1984. Growth performance, nutrient content and human utilization of aquatic macrophytes. The Phytotron, University of Oslo. pp 72.
- BLAKE, G., 1982. Characterization of decomposition of plant material in an alpine lake. Hydrobiol. Bull. 16:5-10.
- BLAKE, G., 1982. Decomposition de la matiere vegetale dans deux roselieres du lac d'Aiguebelette (France). Studies on aquatic vascular plants. pp. 193-198.
- BLAKE, G. and J.P. DUBOIS, 1982. Epuration des eaux: roles des macrophytes aquatiques dans l'elimination des elements mineraux. Studies on aquatic vascular plants, edited by J.J. Symoens, S.S. Hooper and P. Compere. pp. 315-323.
- BONNEWELL, V., W.L. KOUKARI and D.C. PRATT, 1983. Light, oxygen and temperature requirements for *Typha latifolia* seed germination. Can. J. Bot., 61:1330-1336.
- BOTNARIUC, N., O. BOLDOR, Gh. SERBANESCU and St. BELDESCU, 1964. Relatii dintre stof (*Phragmites communis*) si papura (*Typha angustifolia*) in zona inundabila a dunarii. Hidrobiologia 5:165-176.
- BRANDLE, R., 1983. Evolution of fermentation capacity in flooding and anoxia tolerant rhizomes of *Phalaris arundinacea*, *Phragmites communis*, *Schoenoplectus lacustris* and *Typha latifolia*. Bot. Helv. 93: 39-45.
- BRANDLE, R. 1985. Kohlehydratgehalte und vitalitat isolierter Rhizome von *Phragmites australis*, *Schoenoplectus lacustris* und *Typha latifolia* nach mehrwochigem O₂-Mangelstress. Flora 177:317-321.
- BRIX, H. and H-H. SCHIERUP, 1986. Light dependent variations in CO₂, O₂ and N₂ concentrations in the lacunal air of *Phragmites australis*. Botanical Institute, University of Aarhus, Denmark.
- BROCK, T.C.M., G.H.P. ARTS, I.L.M. GOOSEN and A.H.M. RUTENFRANS, 1983. Structure and annual biomass production of *Nymphoides peltata*, Menyanthaceae. Aquat. Bot. 17 (3-4):167-188.

- BROOM, D.M., W.J.A. DICK, C.E. JOHNSON, D.I. SALES and A. ZAHAVI, 1976. Pied wagtail roosting and feeding behaviour. *Birdstudy* 23:267-279.
- BURGERMEISTER, G. and J-B. LACHAVANNE, 1980. The macrophytes. Lake of Pfäeffikon, Switzerland. *Ber. Schweiz. Bot. Ges.* 90 (3-4):213-243.
- BUTTERY, B.R., W.T. WILLIAMS and J.M. LAMBERT, 1965. Competition between *Glyceria maxima* and *Phragmites communis* in the region of Surlingham Broad. II The fen gradient. *J. Ecol* 53:183-196.
- CHAPMAN, V.J., 1939. Studies in salt marsh ecology. Section IV. *J. Ecol.* 27:160-181.
- CHUZHOVA, A.P. and L.Y. ARBUZOVA, 1970. Specific morphological and biological features of aquatic adventitious roots in *Phragmites communis* Trin. *Bot Zh.* 55:1473-1480.
- CONDOR, P., 1964. 13. Notes on the management of the fresh water reed marsh of Minsmere and the salt water lagoons of Havergate Island, Suffolk, England. 160945 IUCN March: 302-316.
- CURRAN, P.L., 1969. Fertility of *Phragmites communis* Trin., Irish Naturalist Journal 16:242.
- DANELL, K., 1978. Food habits of the muskrat, *Ondatra zibethica* (L.), in a Swedish lake. *Ann. Zool. Fennici* 15:177-181.
- DAVIES, N.B., 1976. Food, flocking and territorial behaviour of the pied wagtail (*Motacilla alba yarrellii* Gould) in winter. *J. Animal Ecol.* 45:235-253.
- DAWSON, F.H. and H.B. HALLOWS, 1983. Practical applications of a shading material for macrophyte control in watercourses. *Aquat. Bot.* 17:301-308.
- DE LA CRUZ, A.A., 1974. Primary productivity of coastal marshes in Mississippi. *Gulf Research Reports.* 4:351-356.
- DE JONG, H. and J. PHILIPPONA, 1975. The occurrence of geese in Noordoostpolder and Flevoland. *Limosa.* 48:60-73.
- DE JONG, J. and T. KOK, 1978. The purification of wastewater and effluents using marsh vegetations and soils. *Proc. EWRS 5th Symp. on aquatic weeds.*
- DILL, H.H., 1958. Controlling cattails and *Phragmites* with amitrol. *Proc. Northeastern Weed Control Conf.* 57-58.

- DORKA, V. and J. HOELZINGER, 1974. A new breeding record of the bearded tit *Panurus biamicus* at the nature reserve "Federsee" (9 37' N 48 05' E) with remarks concerning its occurrence in southwest Germany. *Anz. Ornithol Ges. Bayern.* 13:293-299.
- DRAGU, I. and H. ASVADUROV, 1974. The native vegetation of the Crasna Plain as related to soil distribution. *An Inst. Stud. Cercet. Pedol.* 40:281-291.
- DVORAK, J. and BEST, E.P.H., 1982. Macroinvertebrate communities associated with the macrophytes of Lake Vechten, The Netherlands. Structural and functional relationships. *Hydrobiologia* 95:115-126.
- DYKYJOVA, D. and D. HRADECKA, 1973. Productivity of reed-bed stands in relation to the ecotypes, microclimate and trophic conditions of the habitat. *Pol. Arch. Hydrobiol.* 20:111-119.
- DYKYJOVA, D. and D. HRADECKA, 1976. Production ecology of *Phragmites communis*. I. Relations of two ecotypes to the microclimate and nutrient conditions of habitat. *Folia Geobot. Phytotax.* 11:23-61.
- EATON, R.J., 1952. Status of *Phragmites communis* Trin., var. *berlandieri* (Fourn.) Fernald along the Sudbury river in eastern Massachusetts. *Rhodora* 54:135-138.
- EL-SHARKAWI, H.M. and A.A. Fayed, 1975. Vegetation of inland desert woddies in Egypt I. Waddi Bir-El-Ain. *Feddes Reput* 86:589-594.
- ELEUTERIUS, L.N. and H.A. MCCLELLAN, 1976. Transplanting maritime plants to dredged material in Mississippi waters. In: *Proceedings of the Specialty Conference on Dredging and its Environmental Effects*, edited by P.A. Krenkel, J. Harrison and J.C. Burdick III. pp. 900-918.
- ELVEN, R., 1973. Some plant records from Femundsmarka, Central Norway, a phytographical discussion. *Blyttia* 31:229-248.
- FEKES, W. and BAKKER, D., 1954. The genesis of the natural vegetation in the Noordoostpolder. *Van Zee tot Land, Nr 6, Directie van de Wieringermeer (Noordoostpolderwerken)*, Zwolle, 92 pp.
- FERNALD, M.L., 1932. *Phragmites communis* Trin., var. *berlandieri* (Fournier), comb. var. *Rhodora* 34:211-212.
- FIALA, K., 1976. Underground organs of *Phragmites communis*, their

- growth, biomass and production. *Folia Geobot. Phytotax. Bohemoslov.* 11:225-259.
- FINLAYSON, C.M., 1983. Use of aquatic plants to treat wastewaters in irrigation areas of Australia. *Proc. Aust. Water Wastewater 10th Fed. Convention 11-15 April 1983, Sidney.*
- FOGG, J.M., Jr., 1930. The flora of the Elizabeth Islands, Massachusetts. *Rhodora* 32:149.
- GAVENCIAK, S., 1972. Research on water loss by evapotranspiration from water plants. *Vodohospod Cos.* 20:16-32.
- GEISSELHOFER, M. and K. BURIAN, 1970. Biometric studies in the dense stands of reeds of the lake of Neusidl. *Oikos* 21:248-254.
- GELLER, M.S., 1972. *Phragmites*: life preserver of the salt marsh. *Underwater Natur.* 7:4-11.
- GERLACZYNSKA, B. 1973. Distribution and biomass of macrophytes in Lake Dgal Maly. *Ekol. Pol.* 21:743-752.
- GLOSER, J., 1977. Characteristics of CO₂ exchange in *Phragmites communis* Trin. derived from measurements in situ. *Photosynthetica.* 11:139-147.
- GODWIN, H., 1941. Studies in the ecology of Wicken Fen. IV. Croptaking experiments. *J. Ecol.* 29:83-106.
- GOODRUN, P.D. and C.E. Gray, 1958. Experimental control of giant cutgrass in eastern Texas. *Down to earth.* 14:10-12.
- GORHAM, E. and W.H. PEARSALL, 1956b. Production ecology III. Shoot production in *Phragmites* in relation to habitat. *Oikos* 7:206-214.
- GORHAM, J., L.L. HUGHES and R.G. WYN JONES, 1980. Chemical composition of salt-marsh plants from Ynes Mon (Anglesey): the concept of physiotypes. *Plant. Cell Environment* 3:309-318.
- GREINER, R.W. and J. DE JONG, 1984. The use of marsh plants for the treatment of wastewater in areas designed for recreation and tourism. RIJP Report no 225. Lelystad, Netherlands: Rijksdienst voor de IJsselmeer Polders.
- GUINOCHET, J., et al. (Ed.), 1975. International colloquia of the National Center for scientific Research, No 235. Mediterranean Flora. The flora of the Mediterranean Basin. A comprehensive study. Montpellier, France. June 4-8, 1974. ISBN 2-222-01764-5.

- HANCOCK, F.D., 1973. Algal ecology of a stream polluted through gold mining in Witwatersrand. *Hydrobiologica* 43:189-229.
- HARRIS, S.W.B. and W.H. MARSHALL, 1960. Experimental germination of seed and establishment of seedlings of *Phragmites communis*. *Ecology* 41:395.
- HASLAM, S.M., 1965. Ecological studies in the Breck fens. I. Vegetation in relation to habitat. *J. Ecol.* 53:599-619.
- HASLAM, S.M., 1969a. Stem types of *Phragmites communis* Trin. *Ann. Bot. N.S.* 33:127-131.
- HASLAM, S.M., 1971d. Shoot height and density in *Phragmites* stands. *Hydrobiologia* 12:113-119.
- HEMMINGA, M.A. and J. VAN DER TOORN, 1970. Application of Common Reed in the IJsselmeerpolders. *Flevobericht* 73, Rijksdienst voor de IJsselmeerpolders, 31 pp.
- HOCKING, P.J., C.M. FINLAYSON and A.J. CHICK, 1983. The biology of Australian Weeds. 12. *Phragmites australis* (Cav.) Trin. ex Steud. *J. Aust. Inst. Agric. Sci.* 49:123-132.
- HOLISOVA, V., 1972. The food of *Clethrionomys glareolus* in a reed swamp. *Zool. Listy.* 21:293-307.
- HONGVE, D., 1975. The littoral vegetation of Nordbytjernet, a small lake in southwest Norway. *Norw. J. Bot.* 22:83-97.
- HUDEC, K., 1975. The bird synusia of the "Kobylske Jezu" reed swamp (Southern Moravia) during the breeding season. *Zool. Listy.* 24:65-80.
- IMHOF, G., 1979. Arthropod communities connected with *Phragmites* in Neusiedlersee. In: *The limnology of a shallow lake in central Europe*, edited by H. Löffler, Junk Publ. The Hague, Boston, London, 389-397.
- IWATA, E. and K. ISHIZUKA, 1967. Plant succession in Hachirogata polder. *Ecological studies on Common Reed (Phragmites communis)* I. *Ecol. Review (sendai)* 17:37-46.
- JAWORSKI, A.Z. and J.C.F. TEDROW, 1967. Pedologic properties of New-Jersey tidal marshes. *Soil Science* 139: 21-29.
- JENKERSON, C.G. AND M. HICKMAN, 1983. The spatial and temporal distribution of an epiphytic algal community in a shallow prairie parkland lake, Alberta, Canada. *Holarctic Ecol.*

6:41-58.

JUTTNER, F., R. SCHRODER, R. and I. REICHENAU, 1982. Microbially derived volatile organic compounds in the recent sediment of the *Phragmites australis* bed of Lake Constance, Western Europe. Arch. Hydrobiol. 94:172-181.

KAMINSKI, R.M. and H.H. PRINCE, 1984. Dabbling duck-habitat associations during spring in delta marsh Manitoba. J. Wildl. Manage 48:37-50.

KANETA, M. and N. SUGIYAMA, 1972. The constituents of *Arthraxon hispidus* Makino, *Miscanthus tinctorius* Hackel, *Miscanthus sinensis* Anderss, and *Phragmites communis* Trinius. Bull. of the Chemical Society of Japan 45:528-531.

KEMP, D and M. RADDUX, 1982. An ecological and experimental approach to the potential use of *Phragmites australis* and *Carex acuta* for the treatment of wastewaters. Tribune du Cebedeau 35:325-340.

KIENDL, J., 1953. Zum Wasserhaushalt des *Phragmitetum communis* und des *Glycerietum aquaticae*. Ber Dt. Bot. Ges. 66:246-262.

KIM, C.S., 1975. A study on standing crops in *Phragmites communis* communities and their environmental factors. Korean J. Bot. 18:129-134.

KLOTZLI, F. and S. ZUST, 1971. Conservation of reed-beds in Switzerland. Pol. Arch. Hydrobiol. 20:229-235.

KLOTZLI, F. and S. ZUST, 1976. Nitrogen regime in reedbeds. Pol. Arch. Hydrobiol. 20:131-136.

KNOWLTON, C.H., 1912. Notes on the flora of Duxbury, Massachusetts. Rhodora 14:20.

KORELYAKOVA, I.L., 1971. Distribution and productivity of communities of *Phragmites communis* Trin. in Dnieper reservoirs. Hidrobiologia 12:149-154.

KRESOVICH, S., C.K. WAGNER, D.A. SCANLAND and W.T. LAWHON, 1981. Emergent aquatic plants: Biological and economic perspectives. Biomass 1:127-144.

KROLIKOWSKA, J., 1974. Water content in leaves of helophytes. Pol. Arch. Hydrobiol. 21:229-240.

KRULL, J.N., 1970. Aquatic plant - macroinvertebrate associations and waterfowl. J. Wildl. Manage. 34:707-718.

- KUCERA, C.L., 1957. New plant station records in Missouri. *Rhodora* 59:240.
- KUFEL, I., 1982. Phosphorus and alkaline phosphatase activity in some aquatic macrophytes. *Bull. Acad. Pol. Sci.* 30:1-6.
- KVET, J. 1973b. Transpiration of South Moravian *Phragmites communis*. In: Littorial of the Nesyt Fishpond, edited by J. Kvet. pp 143-146 *Studie CSAU* 15/1973. Academia, Praha.
- KVET, J., B. ULEHLOVA and J. PELIKAN, 1973. Structures of the reed-belt ecosystem of the Nesyt Fishpond. *Pol. Arch. Hydrobiol.* 20: 147-150.
- LARSEN, V.J., 1982. The effects of pre-drying and fragmentation on the leaching of nutrient elements and organic matter from *Phragmites australis* litter. *Aquat. Bot.* 14:29-40.
- LEASURE, J.K., 1963. The mode of action of dalapon. *Down to Earth* 19:19-22.
- LEVASSEUR, J., 1971. The fluctuations in coastal hygrophilous vegetation of the south central portion of the Bay of Audienne. *Bot. Rhedonica. Ser. A.* 10:251-292.
- LODH, S.B. and P.R. RAO, 1963. Examination of reeds as raw materials for furfural production. *J. Proc. Inst. Chem.* 35:48-50.
- LONDO, G., 1972. Pattern and process in dune slack vegetation along an excavated lake in the Kennemer Dunes. *Verk. Rijksinst. Natuurbeheer* 2:9-279.
- LOOSJES, M., 1974. Habitat use, disturbances and food of greylag geese *Anser anser* in a brackish area. *Limosa* 47:121-143.
- MCATEE, W.L., 1916. The winter flora of Muskeget Island, Massachusetts. *Rhodora* 18:96.
- MCCORMICK, J. and T. ASHBAUGH, 1972. Vegetation of a section of Oldmans Creek Tidal Marsh and related areas in Salem and Gloucester counties, New Jersey. *Bull. N.J. Acad. Sci.* 17:31-37.
- MCDONALD, R.C., 1981. Vascular plants for decontaminating radioactive water and soils. *NASA RTOP No.* 637-01-02.
- MCMANUS, J., and S.A.K. ALIZAI, 1983. Sediment filled reed *Phragmites communis* stems as contributors to marsh sediment

- fabrics. J. Sediment Petrol. 53:407-409.
- MAIER, R. and H. SIEGHARDT, 1977. Untersuchungen zur primärproduktion im Grunqurtel des Neusiedler See. Teil II *Phragmites communis*. Pol. Arch. Hydrobiol. 24:245-257.
- MASON, C.F. and R.J. BRYANT, 1975. Production, nutrient content and decomposition of *Phragmites communis* Trin. and *Typha angustifolia* L. J. Ecol 63:71-95.
- MELE, J.A. and K.J. GORMAN, 1982. Determination of mercury levels in *Phragmites communis* from a contaminated tidal marsh ecosystem. Bull. N.J. Acad. Sci. 27:41.
- MEREZHKO, A.I., et al. 1974. Change of some physiological and biological indices of *Phragmites communis* Trin. with different mineral nutrition under experimental conditions. Gidrobiol. Zh. 10:90-93.
- MIN, B.M. and J.H. KIM, 1983. Distribution and cyclings of nutrients in *Phragmites communis* communities of a coastal salt marsh. Korean J. Bot. 26:17-32.
- MOCHNACKA-LAWACZ, H., 1974b. Seasonal changes of *Phragmites communis* Trin. Part II: Mineral contents. Pol. Arch. Hydrobiol. 21:369-380.
- MOHLENBROCK, R.H., J.E. OZMENT and C.W. FOLKERTS, 1962. Additions to the flora of Illinois. Rhodora 64:358.
- MONK, L.S., R.M.M. CRAWFORD and R. Brandle, 1984. Fermentation rates and ethanol accumulation in relation to flooding tolerance in rhizomes of monocotyledonous species. J. Exp. Bot. 35:738-745.
- MORET, J-L, 1982. Evolution des roselieres lacustres de la region des Granges entre 1976 et 1982. Bull Soc. Vaud. Sc. Nat. no 362. 62:185-195.
- MORETTI, G., L. ZINNAI and C. ATONELLI, 1962. Experimental evidence of chemical weed eradication in Lake Trasimeno. Revista Hydrobiol. 1:95-114.
- MYARTSEVA, S.N., 1982. New data on Encyrtid wasps, Hymenoptera, Encyrtidae, parasitizing scale insects, Homoptera, Coccoidae of the common reed *Phragmites australis*. Entom. Rev. 61:145-155.
- NIKOLAJEVSKY, V.G., 1971. Research into the biology of the Common reed (*Phragmites communis* Trin.) in the U.S.S.R., Folia Geobot. Phytotax. 6:221-230.

- NISBET, I.C.T. and L. MEDWAY, 1972. Dispersion, population ecology and migration of eastern great reed warblers *Acrocephalus orientales* wintering in Malaysia. *Ibis* 114:451-494.
- OGAN, M.T., 1982. Nitrogenase activity of soil cores of aquatic grasses. *Aquat. Bot.* 13:105-124.
- OGAN, M.T., 1983. Factors affecting nitrogenase activity associated with marsh grasses and their soils from eutrophic lakes. *Aquat. Bot.* 17:215-230.
- ONDOK, J.P., 1968. Measurement of leaf area in *Phragmites communis* Trin. *Photosynthetica* 2:25-30.
- ONDOK, J.P., 1969. The problems of the application of the growth analysis of the investigation of *Phragmites communis* Trin. *Hydrobiologia* 10:87-95.
- ONDOK, J. 1970. The horizontal structure of reed stands *Phragmites communis* and its relation to productivity. *Predlia* (Prague) 42:256-261.
- ONDOK, J.P. and J. GLOSER, 1978. Net photosynthesis and dark respiration in a stand of *Phragmites communis* Trin. calculated by means of a model. *Photosynthetica* 12:337-343.
- OSBORNE, P.L. and J. LEACH, 1983. Changes in the distribution of aquatic plants in a tropical swamp. *Environ. Contam.* 10:323-329.
- PANDIT, A.K., 1984. Role of macrophytes in aquatic ecosystems and management of freshwater resources. *J. Environ. Manage.* 18:73-88.
- PARLANGE, J. and P.E. WAGGONER, 1972. Boundary layer and temperature distribution on still and flapping leaves: II. Field experiments. *Plant Physiol.* 50:60-63.
- PAUTOU, G. et al., 1973. Ecological research, eradication of mosquitoes and protection of nature. *Nat. Belg.* 54:105-115.
- PEARCY, R.W. et al., 1974. Field photosynthetic performance and leaf temperatures of *Phragmites communis* under summer conditions in Death Valley, California. *Photosynthetica* 8:104-108.
- PLANTER, M., 1970. Elution of mineral components out of dead reed *Phragmites communis* Trin. *Pol. Arch. Hydrobiol.* 17:357-362.

- POLUNIN, N.V.C., 1982. Processes contributing to the decay of reed (*Phragmites australis*) litter in fresh water. Arch. Hydrobiol. 94:182-209.
- POLUNIN, N.V.C., 1982. Effects of the freshwater gastropod *Planorbis carinatus* on reed *Phragmites australis* litter. Microbial activity in an experimental system. Freshwater Biol. 12:547-552.
- PRUSCHA, H., 1973. Biology and productive biology of *Phragmataecia castaneae* Hb. (Lepidoptera, Cossidae) Sitzungsber. Oesterr. Akad. Wiss. Math. Naturwiss. Kl. 181:1-49.
- RADOUX, M., 1980. An experimental and ecological approach to the potential use for sewage treatment of the common reed (*Phragmites australis*). Tribune de Cebedeau 33:329-339.
- RAGHI-ATRI, F. and R. BORNKAMM, 1979. Wachstum and chemische Zusammensetzung von Schilf (*Phragmites australis*) in Abhängigkeit von der Gewassereutrophierung. Arch. Hydrobiol. 85:192-228.
- RIBER, H.H., J.P. SORENSON and H-H. SCHIERUP, 1984. Primary productivity and biomass of epiphytes in *Phragmites australis* in an eutrophic Danish lake. Holarc. Ecol. 7: 202-210.
- RICH, W.P., 1908. City botanizing. Rhodora 10:153.
- RICHTER, W.M., 1984. Zur Veränderung der Bestände von *Phragmites australis* (Cavanilles) Trinius ex Steudel (*Phragmites communis* Trinius) im Breiten Lütz bei Feldberg (Mecklenburg). Acta hydrochim et hydrobiol 12:601-607.
- RIEMER, D.N., 1971. Effects of split applications of dalapon on *Phragmites*. Down to Earth 27:7-9.
- RIGG, G.B., 1931. The occurrence of *Phragmites communis* in western Washington and Oregon. Rhodora 33:170-171.
- RIVOLA, M. and M. VONDRACEK, 1972. Zonation of mosses on the banks of the Nový Čepský Pond. Predlia (Prague) 44:359-363.
- ROBSON, T.O., 1967. Accurate aerial application of dalapon to drainage ditches in Britain. Down to Earth 23:12-14.
- ROBSON, T.O., E.C.S. LITTLE, D.R. JOHNSTONE and R.F. HILL, 1966. A new technique for the accurate aerial application of herbicides to drainage channels with negligible spray drift. Weed Res. 6:254-266.

- ROLLINGS, C.T., 1959. Use of herbicides in the improvement of marsh habitat for waterfowl on national wildlife refuges in the upper midwest states. Northcent. Weed Control Conf. Proc. 16:41.
- ROOS, P.J., 1982. Fate and final distribution of dead reed stems in lake Maarseveen, The Netherlands. Hydrobiol. Bull. 16:113-114.
- ROOS, P.J., A.F. POST, and J.M. REVER, 1981. Dynamics and Architecture of reed periphyton. Assoc. Int. Limnol. Theor. Appl. Trav. 21:948-953.
- SASTROUTOMO, S.S., 1982. Summer biomass of aquatic macrophytes in relation to sediment characteristics in lake Aino-numa-numa, Miyagi, Japan. JPN. J. Ecol. 32: 45-56.
- SATYANURTY, T.V.C. and V. SESHAVATHARAM, 1984. Sterility in *Phragmites communis*. Current science 53:1158-1159.
- SEIDEL, K. and H. HOPPEL, 1975. Hoherer Pflanzen als Eliminations-Faktor-Bei Kunststoff-Dispersionen. Naturwiss. 62:351.
- SERENOV, A.G., 1974. Effect of mowing times on regeneration of reed and reedmace growth. Gidrobiol. Zh. 10:61-65.
- SHERF, E.E., 1912. The vegetation of Skokie Marsh, with special reference to subterranean organs and their inter-relationships. Bot. Gaz. 53:415-435.
- SIEGHARDT, H., 1973. Utilization of solar energy content of different organs of *Phragmites communis* Trin. Pol. Arch. Hydrobiol. 20:151-156.
- SKUHRVY, V., 1981. The influence of invertebrates on the production of reed in cze. In: Invertebrates and vertebrates attacking Common reed stands (*Phragmites communis*) in Cze. Ed. Skuhravy, V., Studie CSAV, c.l., Praha, 81-87.
- SKUHRVY, V., V. POKORNY, M. SKUHRVA, 1975. Arthropods (*Lipara* spp., *Stenotarsonemus* sp. and Lepidoptera-larvae) causing suppression of inflorescence in the common reed (*Phragmites communis*). Acta Entomol. Bohemoslov. 72:87-91.
- SMIRNOVA, N.N., 1975. Effect of exogenous amino acids on productivity of certain higher hydrophytes. Gidrobiol. Zh. 11:47-53.
- SMIRNOVA-GARAEVA, N.V., 1972. Coastal-water vegetation of the

- lower reaches of the Drestr. Izu. Akad. Nauk. Mold. SSR. Ser. Biol. Khim. Nauk.
- SMITH, L.M. and J.A. KADLEC, 1983. Seed banks and their role during drawdown of a north American marsh. J. Appl. Ecol. 20:673-684.
- SPITZER, G., 1972. Seasonal aspects of the bearded tit (*Panarus biarmicus*). J. Ornithol. 113:241-275.
- SPRINGER, P.F., 1959. Report on the research coordination committee, catachory aquatics. Northeast Weed Control Conf. Proc., Sup. 13:91-109.
- STAKE, E., 1967. Higher vegetation and nitrogen in a rivuler in central Sweden. Schweiz. Z. Hydrobiol. 29:107-124.
- STAKE, E., 1968. Higher vegetation and phosphorus in a small stream in central Sweden. Schweiz. Z. Hydrobiol. 30:353-373.
- STALTER, R., 1975. *Phragmites communis* in South Carolina. Rhodora 77:159.
- STEENIS, J.H., E.B. CHAMBERLAIN and R.A. BECK, 1959. Recent developments in p control. Proc. 13th Annual Meeting Northeast Weed Control Conf. New York, NY. pp. 293-298.
- STEPHENS, J.C., et al. 1962. Retardance effects and control of water weeds in drainage and irrigation canals in the southeast. U.S. Soil Conserv. Res. Div., Ft. Lauderdale, FL., Mimeo Rpt., 23 pp.
- STEWART, K.K., 1970. Nutrient removal potentials of various aquatic plants. Hyacinth Contr. J. 8:34-35.
- STUDER, C and R. BRANDLE, 1984. Sauerstoffkonsum und versorgung der Rhizome von *Acorus calamus* L., *Glyceria maxima* (Hartmann) Holmberg, *Menyanthes trifoliata* L., *Phalaris arundinacea* L., *Phragmites communis* Trin. und *Typha latifolia* L. Bot. Helv. 94:23-31.
- SVENSON, H.K., 1927a. Effects of post-pleistocene submergence in eastern North America. Rhodora 29:107-114.
- SVENSON, H.K., 1927b. Effects of post-pleistocene marine submergence in eastern North America. Rhodora 29:60-68.
- SZAJNOWSKI, F., 1970. The relations between the reed standing-crop and fishery effect. Pol. Arch. Hydrobiol. 17:363-371.

- SZAJNOWSKI, F., 1973. Relationship between leaf area index and shoot production of *Phragmites communis* Trin. Pol. Arch. Hydrobiol. 20:257-268.
- TADZHITDINOV, M.T. and K.N. BUTOV, 1972. Changes of plant communities in overgrown bodies of water of the Amu-Darya Delta. Ekologiya 3:64-68.
- TADZHITDINOV, M.T. and K.N. BUTOV, 1972. Changes of plant communities in overgrown bodies of water of the Amu-Darya Delta. Ekologiya 3:64-68.
- TAYLOR, N., 1939. Salt tolerance of long island marsh plants. N.Y. St. Mus. Cir. 23:1-42.
- THIEGS, B.J., 1955. The stability of dalapon in soils. Down to Earth 11:2-4.
- TIMMERMANS, J.A., 1961. Lutte centre vegetation aquatique envahissante. sta. de Rech. des Eaux et Forêts, Guanendael-Hoeilaart, Belgique. Trav. Serie D-Hydrobiol. No. 31, 44 pp.
- TROLLENIER, G., 1982. Effect of soil temperature on nitrogen fixation on roots of rice *Oryza sativa* cultivar Cigalon and reed *Phragmites communis*. Plant Soil 68:217-222.
- UTERMOEHL, H., 1982. *Phragmites australis* stands damaged by periphyton of *Cladophora glomerata* in the Lake Grosser Poener see, West Germany. Arch. Hydrobiol. 95:487-490.
- VAN DER TOORN, J., 1966. Advice with respect to the amount of reed seed needed for sowing in the Zuidelijk Flevoland polder, Internal report Nr 20. Rijksdienst voor de IJsselmeerpolders, Zwolle, 7 pp.
- VAN DER TOORN, J., 1979b. Effect of cutting on reed performance. Verh. Kon. Akad. Wetenschappen. Afd. Natuurkunde, Tweede reeks, 73:335-339.
- VAN DIJK, A.G.F., 1982. Sheep grazing in a new polder. Aspects influencing structure and development of the vegetation. Acta Bot. Neerl. 31:144
- VARENKO, N.I. and I.P. LUB'YANOV, 1973. Accumulation of trace elements Mn, Zn, Cu and Co by some hydrophytes of the Dnieprozerhinsk and Zaporozhye Reservoirs. UKR. Bot. Zh. 30:163-168.

- VESTERGAARD, P., 1985. Effects of mowing on the composition of Baltic salt-meadow communities. Preliminary results. *Vegetatio* 62:383-390.
- VOROB'EV, V.I. and E.I. AFANAS'EVA, 1973. Content of some trace elements in macrophytes of the Volga Delta. *Gidrobiol. Zh.* 9:75-77.
- VORONOV, A.G. and R.O. GEODAKYAN, 1972. The formation of phytocenoses on the liberated ground of Lake Seven. *Biol. Zh. Arm.* 25:72-78.
- WAITZBAUER, W., 1971. Aspects of productivity in reed-feeding insects. *Verh. D. Tsch. Zool. Ges.* 65:116-119.
- WALLSTEN, M., 1982. Changes in aquatic vegetation of eutrophic lake Tamnaren. *Studies on aquatic vascular plants*, edited by J.J. Symoens, S.S. Hooper and P. Compere, Roy. Bot. Soc. Belg. pp 293.
- WARD, P., 1968. Fire in relation to waterfowl habitat of the Delta marshes. *Proc. Ann. Tall Timbers Fire Ecol. Conf.* 255-267.
- WEINTRAUB, D., 1933. A preliminary account of the aquatic and subaquatic vegetation and flora of Witwatersrand. *J. Ecol.* 21:44-57.
- WESTLAKE, D.F., 1982. The primary productivity of water plants. *Studies on aquatic vascular plants*, edited by J.J. Symoens, S.S. Hooper and P. Compere, Roy. Bot. Soc. Belg. pp. 165-180.
- WHITE, D.A. 1983. Plant communities of the Lower Pearl River Basin, Louisiana. *The Am. Midl. Naturalist* 110:381-392.
- WIEGERS, J., 1982. Developments in peatland forests in Northwest Overijssel, Netherlands, over a period of 10-15 years. *Acta Bot. Neerl.* 31:498.
- WOLVERTON, B.C. and R.C. McDONALD, 1981. Natural processes for treatment of organic chemical waste. The 1981 National association of environmental professionals conference of toxic and hazardous substances: a unifying concept for the environmental profession in the 1980's. *Environ prof* 1981. 3:99-104.
- WRIGHT, J.E. and G.E. SPATES, 1972. Laboratory evaluation of compounds to determine juvenile hormone activity against the stable fly. *J. Econ. Entomol.* 65:1346-1349.

YAMASAKI, S and I. TANGE, 1981. Growth responses of *Zizania latifolia*, *Phragmites australis* and *Miscanthus sacchariflorus* to varying inundation. *Aquat. Bot.* 10:229-239.)

END

DATE
FILMED

4-87

DTIC