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THE EUROPEAN REED BEDS AND THEIR ECOLOGY WITH AN EXAMPLE FROM THE FRISIAN ISLANDS IN THE NORTHERN SEA

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Introduction

Mr. Gouverneur Kunimazu, Mr. Mayor Furukawa, Ladies and Gentlemen, thank you very much for your invitation to accompany this International workshop to Kusatzu. I have been many times in Japan and I have seen many beautiful places with impressive culture and marvellous nature in your country and in meantime I am a big friend of Japan. In my lecture I want to compare specific ecological and biocoenological details concerning the Reed beds in Europe and in the Holarctic.

Without doubt *Phragmites australis* is the most competitive of all the European water plants and Reed-elements of non-brackish stagnant waters. Its ecological and sociological amplitude is equally large and it extends from lime-oligotrophic and acid-oligotrophic to eutrophic waters and from deep water to ground which from time to time is above the water surface. Common Reed may occur in fen meadows, but it does not have the strong negative effect upon the performance of other species as first supposed (s. GÜSEWELL & EDWARDS 1999).

The plant communities formed around *Phragmites australis* are correspondingly numerous and varied within the holarctic order of *Phragmitetalia australis* (common Reed-swamps) and their varying habitats are however similar throughout wide areas from Europe. Even in the highland of south west Japan there are parallels to the floristic composition of the European Reed-swamps (s. KLÖTZLI 1971, GÜSEWELL & KLÖTZLI 1998).

Many of these pioneers in aquatic ecosystems are able to assimilate even when they are submerged by high water (e.g. *Scirpus lacustris, Typha latifolia, Typha angustifolia*). These Reed-species are like helophytes with heights of 3.5 m, their aerial parts have become strongly xeromorphic and their transpiration-rate is similar to land plants. Typically are further strong vegetative growth, which begins at a temperature about 8°-10° C, so the young shoots appear immediately. Frost damage increases at about -8.7° C; that means nearly all Reed-species require a certain length of phytosynthetically active period and of rest period in winter to be able to develop normally (s. POTT 1980, 1992, 1995a).

That is the reason for clear distribution limits of the European Reed in southern Scandinavia and in the montane belt of the Central European mountains, whereas it grows well in the subtropical regions and its distribution is world wide.

The productivity of Reed stand in Europe is very well known. The annual amount of dry organic matter produced above ground is about 17 t/ha; that is similar to the production of wheat. The denser the stand, the higher the productivity, but there is a great variation from year to year depending on the weather, the quality of water and the nutrient content of the habitats

(KLÖTZLI 1974).

In nutrient-rich lakes we find typical species and animal-rich biotope-types, dominated by Reed-belts or Reed-swamps. The Reed-swamps build up a typical biocoenosis as the result of a long co-evolution of Reed and adapted animals. In certain respects the Reed-swamp represents a natural monoculture since *Phragmites* can dominate over several square kilometres. In this case the Reed contributes nearly 70-90% of the primary production.

Usually these Reed-plant communities are stable, they can be managed by cutting and mowing for many years without any noticable falling off in production OSTENDORP (1987). Sometimes Reed can survive the complete drying out of the habitats several times. Sometimes the hugh *Phragmites* stand around lakes show in small circular areas collapse and they die, especially where the rhizomes have formed a thick mat. Such a *Phragmites*-dieback can be observed with small gaps, which can be close up again within a few years. Accumulation of luxuriant nutrients or poissonous substances in the rhizomes of *Phragmites* may be the cause for larger spreading gaps. These problems will be discussed in the lecture.

Key Words: European Reed-beds, *Phragmitetea australis,* productivity, biocoenosis, Phragmites-dieback

Coenotic biodiversity of Phragmites australis reeds in Europe

This lecture deals with tall pioneer vegetation in the marshland areas on the banks of lakes and rivers and is focussed at first to the dune slack of the islands in the Northern Sea, resp. the island of Norderney (figs. 1 and 2). The coastal dunes can only be formed where wind blows over stretches of bare sand. A series of plant communities takes part in the formation and further development of the coastal dunes. Here the beach is still undisturbed. These dunes and dune



Fig. 1 Wadden Sea area and islands of the North Sea (from PETERSEN 1999).



Fig. 2 The Wadden Sea island Norderney (from POTT 1995b).

slacks are arranged in a characteristic order in zones one behind the other. These zones are largely brought about a succession which is shown in fig. 3 and 4. The white dunes can build up a bank which can get up to over 10 m in height (s. POTT 1995b, 1996).

The dune landscape is sometimes further diversified when the sea brakes through or deep cuts are made by the wind resulting in more or less wide slacks. Such channels may be blown out right down to the capillary layer above the groundwater. And should this happen in summer, when the water level is low, these depressions may be to deep that they fill with water to form lakes and mires (s. figs. 3 and 5). These inundated dune slacks with their clear and acid or basic water - mostly poor in nutrients - build habitats for a lot of various vegetation units which stay in very complicated interaction to each other and have a special type of succession (s. fig. 4, PETERSEN 1999). This vegetation - called hygrosere - depends on the groundwater level. Therefore the succession from vegetation units of *Littorelletea to Phragmitetea* is characteristic (figs. 6 and 7).



Fig. 3 View in a secondary dune slack in winter on the Wadden Sea island Sylt (from POTT 1995b). Secondary dune slacks are the result of intense sand-blowing in dune complexes. The blowing of sand will carry on until the capillary zone of the water level has been reached. It is typical that the dune slacks are flooded during winter and most of spring because of the large precipitation surplus in these months, whereas they fall drained during summer as a result of high evatranspiration. Such seasonal fluctuation of the water table is necessary for the occurence of the characteristic vegetation in this ecosystem.

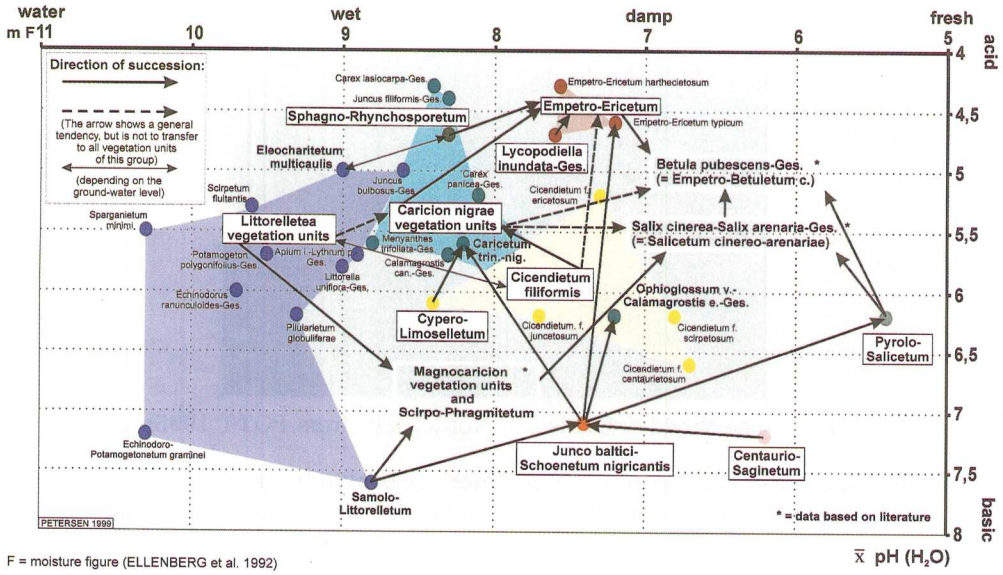


Fig. 4 This scheme shows the succession (development of vegetation) within dune slacks. Vegetation of dune slacks is very diverse and characterized by high species diversity. Under natural conditions, this vegetation develops from pioneer stages into herbaceous vegetation and finally into a closed vegetation of shrubs and woodland. Changes in the abiotic conditions such as acidification and hydrology are the main determinants of the changes in communities and are therefore the basis for this succession scheme. Giving a general view the plant communities of higher syntaxonomical level are put into different colours: blue-wet pioneer vegetation (*Littorelletea*), yellow-pioneer vegetation with anthropogenic-zoogenic influence (*Isoëto-Nanojuncetea*), pink-brackish pioneer vegetation (*Saginetea maritimae*), orange-calcerous fen vegetation (*Scheuchzerio-Caricetea nigrae, Caricion davallianae*), green-acid fen vegetation (*Scheuchzerio-Caricetea nigrae, Caricion nigrae*), brown-intermediate mire vegetation (*Scheuchzerio-Caricetea nigrae, Rhynchosporion*), red-heath mire (*Oxycocco-Sphagnetea*), grey-willow shrub (*Calluno-Ulicetea*) (from PETERSEN 1999).

Main reasons for this succession are a decrease of the groundwater level and the process of eutrophication. Often the Reed-vegetation develops into stages of bushes of birches and willows. The *Phragmitetea*-vegetation may occur on wet (sometimes brackish) places in dune slacks in the entire area. Sometimes they extend into open water of dune lakes. Other typical Reed-vegetation on the islands are places where fresh water seeps from the bordering dune or Pleistocene areas.

A special kind of locations are man made "Polder"-landscapes (parts of the coast surrounded by new built sanddikes in order to reclaim new land) which are mostly in a status of very marvellous and valuable wetland because of the occurence of many rare and endangered vegetation units and their associated fauna (s. fig. 5). There are also in coastal marsh regions big and important areas of Reed-vegetation (s. fig. 8) e.g. on highest marshes of estuaries or in the brackish and tidal freshwater parts in estuaries (DIJKEMA & WOLFF 1983). In such landscapes, especially in the northern parts of Germany an old tradition of Reed-landuse has developed because the roofs of the houses in this region - Frisian houses - have been thatched with Reed (fig. 9). Further the



Fig. 5 Man made "Polder"-landscape with artificial Reed beds.



Fig. 6 A typical plant community of dune slacks on the Wadden Sea islands with Shore-weed (*Littorella uniflora*) and Water Pimpernel (*Samolus valerandi*). This vegetation unit is characteristic for calcerous and often brackish sites (from PETERSEN 1999).



Fig. 7 Reed bed (*Scirpo-Phragmitetum*) in a dune slack after succession, drying-up and organic soil development.



Fig. 8 Man made Polder on artificial sheets of water and large Reed beds extendedly developing into woodland (Südstrandpolder, Norderney).



Fig. 9 Frisian-house thatched with Reed, a typical way of building roofs at the North Sea coast (Nieblum, Föhr).

coastal Reed-vegetation became important for protection of seashore.

The helophytes are the dominant lifeforms in Reed-swamps; these are characterized by their surviving buds which are located under water in the upper layers of sediment, whereby the developed shoots assimilate above the surface of the water. Sweet and sour grasses (Gramineae and Cyperaceae) dominate this aspect and form polycorms and as a result of vegetative reproduction and consequently joined by runners, rhizoms or other organs. Because a polycorm originates from a single mother plant, it is, genetically speaking, a clone or part of a clone; the originally uniform system of rhizomes or runners tends to die out from the rear over a period years, so that, from a formal point of view, several polycorms are gradually created from a single plant.

As far as we know today, there is only one class, *Phragmitetea australis, w*hich belongs to this formation in Europe; this emphasizes its unique structural and ecological position.

Reeds are plant stands which grow in or close to water and which are characterized physiognomically by *Phragmites australis* (= *P. communis*) and morphologically similar plants, such as grasses, bulrushes and reedmace (*Schoenoplectus lacustris, Typha angustifolia, T. latifolia,* s. fig. 10).

Because the reed beds and reed species such as hydrophytes or helophytes grow in water-saturated substrate, it is plausible that they are also rich in aerenchyma. Aerenchyma may also play a certain role in the mechanics of the helophytes, because it makes a cylindrical arrangement of main bundles possible and provides good stability despite the light weight of the stalks. This is particularly important for shallow root systems; a shallow root system is on the other hand a result of the low oxygen availability in the soil.

It has been found that plants which grow in habitats, which are flooded from time to time, have acquired characteristic features in the metabolism of their cells which can be understood as a biochemical adaptation to a shortage of O_2 (s. CRAWFORD 1972). The species, which have been examined with respect to this phenomenon, thus far do indeed belong to very different plant communities, because long lasting coverage with water in particular is typical for this formation (s. table 1). Plants in "normal" terrestrial habitats, which are subjected to anaerobic conditions at



Fig. 10 Great Reedmace (*Typha latifolia*) and Bulrush (*Schoenoplectus lacustris*).

Tab. 1 synopsis of the Reed and Sedge beds and their character species in Europe from ELLENBERG (1996)

Character spezies of the class and order of **Reed and Sedge beds** (Phragmitetea, Phragmitetalia):		
Acorus calamus	*Poa palustris* (4)	
Alisma plantago-aquatica	A *Sagittaria sagittifolia* (1)	
Equisetum fluviatile	*Scirpus mucronatus*	
Iris pseudacorus	*S. lacustris* ssp. *tabernaemontani* (2)	
Character species of the four alliances:		
1. True Reed swamps (Phragmition)	**3. Stream Reed swamps** (Sparganio-Glycerion)	**4. Large Sedge swamps** (Magnocaricion)
Butomus umbellatus	*Apium nodiflorum*	A *Carex appropinquata*
Eleocharis palustris (K)	A *Berula erecta*	*C. distans*
A *Glyceria maxima*	*Epilobium parviflorum*	A *C. paniculata*
Hippuris vulgaris	*E. roseum (?)*	A *C. pseudocyperus*
Oenanthe aquatica (K)	*Glyceria fluitans*	A *C. riparia*
A *Phragmites australis* (K)	*G. plicata*	A *C. vesicaria*
Ranunculus lingua	*Nasturtium officinale*	A *C. vulpina* (?)
Rorippa amphibia	*Scrophularia umbrosa*	*Ciccuta virosa*
Rumex aquaticus (K)	*Veronica anagallis-aquatica*	*Cyperus longus*
R. hydrolapathum	*V. beccabunga*	*Eleocharis uniglumis*
A *Scirpus lacustris*		*Galium palustre*
Sium latifolium (?)		*Oenanthe fistulosa*
Sparganium emersum (K)		*Peucedanum palustre*
S. erectum ssp. *polyedrum* (K)		*Scutellaria galericulata*
A *Typha angustifolia*		*Teucrium scordium*
A *T. latifolia*		
		4a in the suballiance Caricion elatae:
2. Shore Rush-Reed beds (Bolboschoenion)*)	In Reed and Sedge swamps	A *Carex elata*
		A *C. rostrata*
		Lysimachia thyrsiflora
A *Bolboschoenus maritimus*		*Senecio paludosus*
Scirpus pungens	A *Cladium mariscus*	4b sa Caricion gracilis:
S. triqueter	A *Phalaris arundinacea* (K)	A *Carex gracilis*

Note: A = characterspecies of a community (generally an association) which is named after it (usually the dominant species).
(K) = looked upon as a class character species by many authors.
(1) etc. can also serve as character species for the relevant alliance.

*) Some of the species are no longer looked upon as character species (see section E III 1. No. 1.4).

Source: After Tüxen, Preising, Oberdorfer and other authors.

their roots in exceptional cases only, tend to perform an alcoholic fermentation in place of complete cell respiration; high concentrations of ethanol in the cells have a harmful and even fatal effect. A number of species which settle regularly on wet ground form harmless malic acid as the final product of respiration. A large number of "harmless" final products of the respiration metabolism have become known for many plants, an interesting parallel to the animal kingdom, and it remains to be seen in how far they are coupled with a particular ecological constitution.

Phragmitetea australis - Reed beds and sedge marshes

Reed and sedge-beds are widespread all over the Holarctic. Similar associations deriving from closely related species live in other phytogeographical kingdoms; this is most probably a cosmopolitan class.

The floral and habitat-related rough division is given in table 1. Many index species of higher syntax reach a maximum of quantity and consistency in low units and, as a result, are also considered index species, although they show only little bonding.

The class presents a good example of the initially confusing differences in the systems which can be traced back to different classifications of particular "blocks" of associations, which are clearly closed "related": Thus become transparent (s. POTT 1998a/1998b). Consequently, the class *Bolboschoenetea* (brackish water and tide reeds) is now sometimes only listed as an alliance of the *Phragmetetalia.* In the same way, it is possible to draw different borders between the eu- and the oligotrophic sedge marshes (s. fig. 10, WILMANNS 1973, 1998 and POTT 1992, 1995a, 1996).

The ecological differences between the alliances: a vegetation profile of a free lake surface to a higher area on the bank (examples fig. 11) illustrates the qualitative difference between reed alliances and *Magnocaricion*: a higher level above the lake's surface and the water table results in less flooding; this means that the *Magnocarcion* stands dry out superficially from time to time; their surface ground is aerated better (assuming the same type of soil). In terms of quantity the relationships are not as clear: the borders between the alliances do not appear at the same level above the water table in different regions, because the hydrologic balance is also determined by the differing types of soil and amounts of precipitation: however, it is the entire water balance which decides on the survival chances for the plant, not any single habitat factor.

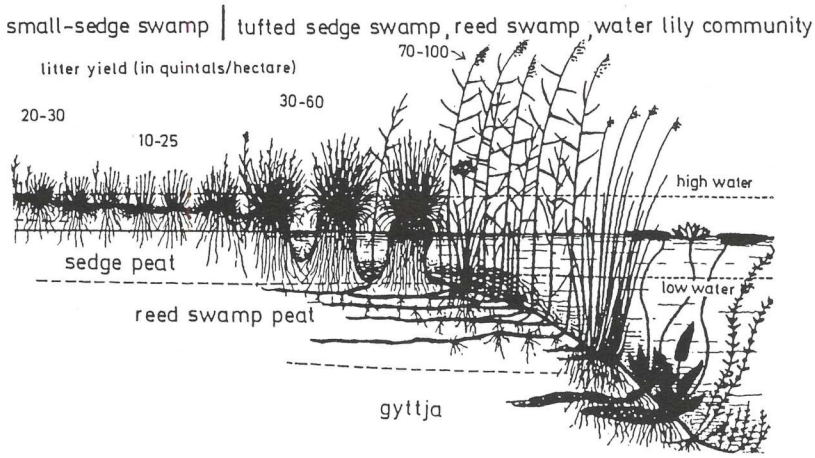


Fig. 11 Multiple zonation of plant communities at a nutrient-rich lake in southern Germany after the natural woodland has been destroyed (modified from ELLENBERG 1988).

(1) Slackwater-Reeds

As a result of drainage and bank reinforcement, slackwater reeds should have experienced an overall decline, but these plants have, in fact, won such new biotopes as flooded gravel pits and loess catchment basins. - At the heart of the *Phragmition,* there is a very loosely defined Scirpo-*Phragmitetum* australis, AC *Phragmities australis* opt., *Schoenoplectus lacustris, Typha angustifolia, T. latifolia* (s. figs. 10-12). This collective association is often divided into several associations. The most prominent contrast is formed by the *Schoenoplectus* stands; the other species often populate different habitats locally, but they can also be found in mixed stands; as distinctive polycorm formations, they form the facies of the association. In the composition of the *Scirpo-Phragmitetum,* the speed and the chance of first settlements also play a role at new formed growing locations. The combination of species and the corresponding structure are very



Fig. 12 Zonation of a drying-up lake with the zone of water plants (zone of Reed with *Phragmites australis* and zone of swamp forest. The succession always develops into woodland).

important in terms of community ecology (s. POTT 1980, 1983, WILMANNS 1973, 1998 and ELLENBERG 1988, 1996).

Schoenoplectus lacustris is a pioneer plant which advances to water depths of up to five meters (s. fig. 11). Its chlorophyll-carrying, leafless, aerenchymatic caulomes are not very resistant to breakage and only appear in very calm waters. If it is proven that lake rushes and similarly composed relatives (*Sch. tabernaemontani, Sch. littoralis* in the southern hemisphere) also assimilate under water, this would be an explanation for the fact that these species are able to advance further into lakes than *Phragmites* and others, competition to which they lose the battle on inland territories. The micro-organism flora which settle on *Schoenoplectus lacustris* plays a special role in biological self-cleaning because they can absorb substances which are difficult to eliminate from the water, particularly phenol. These plants process them into substances which can be more easily decomposed.

In the silt belt, *Phragmites* or *Typha* dominanted stands tend to adjoin towards the top. Reeds primarily use a system of vegetative reproduction by a network of rhizomatous runners. DNA fingerprinting analyses reveal that the genetic makeup of entire reed populations in many lakes is identical, that millions of ramets originate as one genet from a single successful seed germination (NEUHAUS *et al.* 1993, WILMANNS 1998). Does this type of homogenous cloning encourages "reed die-back"? We will see later. This generative reproduction shows other signs of tropical origin: it blooms in the summer, the seeds are ripe starting in January, their germination is most successful at 27° to 36° C and quickest under edgewater conditions, not in the water. On moderately nutrient-rich soils, where the index species of the following associations do not yet appear, *Phragmites* forms closed herds. This does not mean that it would be impaired by the addition of nutrients; on the contrary: it can grow to a height of 4 m close to sewage lines and in small sewage treatment basins with soil filters. This "achievement" is based on

- the high possible productivity of the plant, i.e. the incorporation of ions from the substrate which has seeped through, and

- the discharge of oxygen from the aerenchymatic roots;

this creates a mosaic of reducing and oxidizing conditions in the substrate, which in turn

encourages a number of different micro-organisms responsible for decomposition (s. DIERSSEN 1996, WILMANNS 1998).

Reed beds with dominant *Glyceria maxima* are named phytosociologically as *Glycerietum maximae*. They are growing on very nutrient rich habitats. Normally this graminee which can reach a height of 1.50 m, forms the reed bed in the shore areas affected by human eutrophication, where polluted rivers flow into the lake. There the plant can gather loose sludge and use runners to form quagmires in areas which cannot be trampled by animals. The fact that the plant asserts itself under favourable conditions with respect to the reeds which grow thicker and higher can be convincingly attributed to the earlier shoots of the *Glycerietum maximae*: it shades the soil so well from the beginning of May that other species, such as the *Phragmites* shoots which bud later can no longer compete (s. POTT 1983, 1995b, WILMANNS 1998).

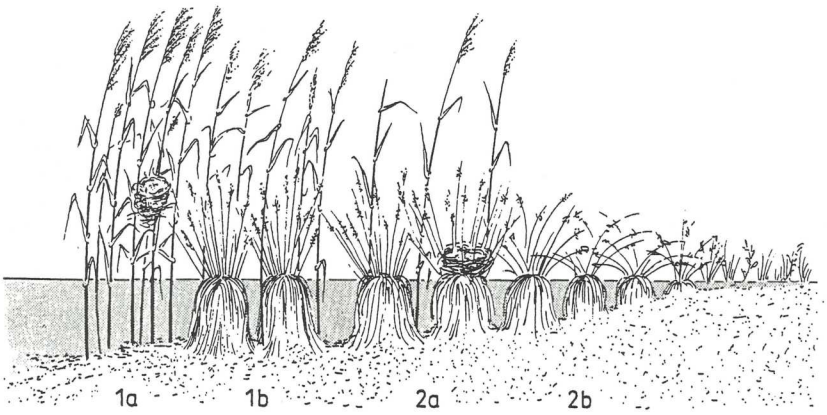
The community ecology of Phragmitetea-reeds

Despite its barrenness of cormophytes and particularly of flowers, an old reed bed hosts a lot of animals: one advantage is that reeds and reed-mace with high and hollow stalks overwinter, and they are very similar to wood for animals. The richness of adapted invertebrate phytophagous insects can be understood on the basis of the surely high age of the formation. There are also birds in large numbers; more than a hundred different species, have been counted in the large reed areas at the Reed beds of German Coasts (figs. 13-17). This clearly results from the position of the *Phragmitetea* stands between the open water surface and the alga terrain, whereby the resources available in both areas can be easily reached by mobile organisms. Essential are the different requirements made on the structure and contact vegetation in reed beds by different species of birds, i.e. how they find their ecological niche and avoid competition to three basic functions of plant societies for animals: providing structure, a supply of food and a signal for the habitat selection (s. figs. 13-17).

Dangers and protection of reed beds

The biocoenological value of reed beds in general and of sedges in particular is reflected in the important way in which these belts protect the shoreline; *Phragmites* also plays the major role in providing protection against erosion with its wide network of rooted rhizomes. As a result, the widespread decline of reed beds with *Phragmites* dominance can be considered as dramatic in some areas. As a phenomenon and in terms of scientific methods, it displays parallels to the "recent forest decline"; "tree/forest die-back/decline" that is a kind to a "reed die-back/decline", whereby reed signifies the plant *Phragmites* as well as the *Phragmites* reed bed and reeds in general (s. fig. 18).

Since the 1940s, there have been reports of the formation of small holes with rotting rhizomes and widespread die-back at more than 35 lakes from Great Britain to Hungary. In the lakes round Berlin in Germany while 37.5 km, or 40 % of the shoreline, were still covered with reeds in 1962, only 23 % was covered by 1972; the areas had actually shrunk by 50.4 % according to several publications by LANG (1967), SUKOPP *et al.* (1975), KLÖTZL & GRÜNING (1976), OSTENDORP (1990, 1993), BLAB (1993) and KRAUSS (1992). This had a particularly severe effect on the reeds themselves and on the bird fauna as well, whereby *Acorus calamus* was advancing. The causes were predominantly mechanical in nature (sport boats and their tracks, buildings on the shoreline, etc.), as well as gnawing done by muskrats (*Ondatra zibethica*); eutrophication was named as a factor only later. It cannot be denied that other anthropogenic



Acrocephalus scirpaceus (Scirpo-)Phragmitetum typ. in *Phragmites*-Fazies (1a) *Typha*- and *Scirpus lacustris*-Fazies	favorite nesting place also excepted	***Emberiza schoeniclus*** Caricetum elatae, Subass. of *Phragmites* (2a) (Scirpo-)Phragmitetum, Subass. of *Carex elata*
nest sticks in the reeds	nest-building	nest in flooding safe hursts
near the nest in (Sc.-)Phragm. and at the bottom of the store and in the midst of the bushes	singing observatory	on top of reed culms and in the upper store of bushes
	habitat structure altogether:	
attractive	open water surface	in extreme avoided
uniform stock	vegetation complex	mixture of different communities

Fig. 13 Biocoenological details concerning the Reed beds (from WILMANNS 1998).



Fig. 14 Reed Warbler (*Acrocephalus scirpaceus*).



Fig. 15 Reed Warbler in the nest (*Acrocephalus scirpaceus*).

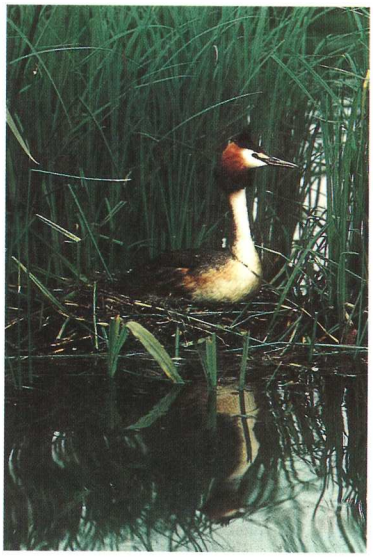


Fig. 16 Great-Grested-Grebe on the nest (*Podiceps cristatus*).

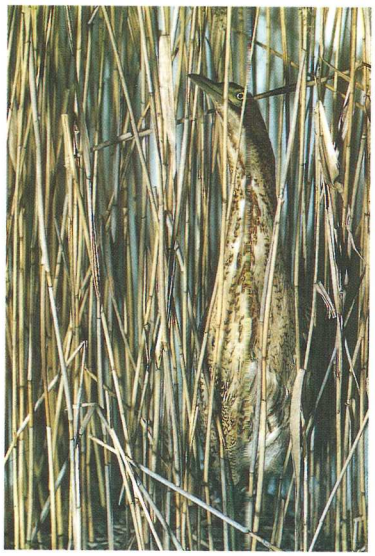


Fig. 17 Bittern (*Botarus stellaris*).



Fig. 18 Reed die-back and remaining stands of *Phragmites australis*.

mechanical factors have been the causes of destruction close to the shoreline. More attention was then paid to nutrient accumulation: the postulated connection of the ecological system can be represented in diagram form in fig. 19. This gave rise to the (most certainly just) demand for better waste water treatment; however, it was also suggested that the reeds should be cut.

Diverse and long-term studies made at Lake Constance, which is severely affected, now allow us to paint a different picture (s. fig. 20). In addition to buildings along the shoreline, the triggers include meteorological-hydrological factors; by comparison, neither the earlier increase in trophie

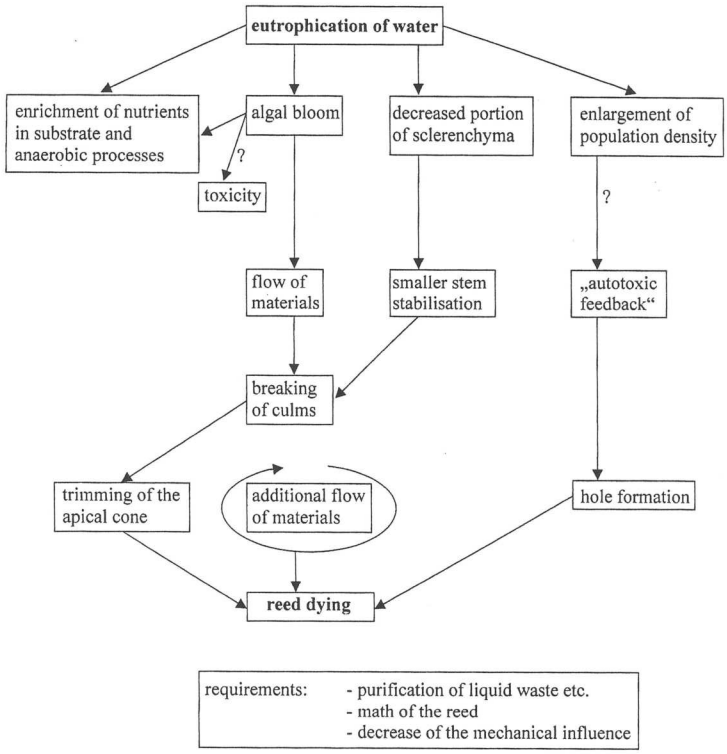


Fig. 19 Postulated causal connection between eutrophication as the cause and reed dying as the consequence (modified from WILMANNS 1998).

nor the more recent decline coincides with the reed die-back, at least in this area, nor is the nutrient content of the sediment intolerable for *Phragmites,* nor can sapropel and insufficient redox potential be the causes. The course of three years with unfavourable climatic conditions for the reeds, with storms, hail and extreme flooding in particular, which occur in the summer for the lakes at the border of the Alps, can be considered as a decisive factor. It was not possible to immediately compensate for this devitalization due to nutrient loss at a time when the rhizomes were empty. The decline of the reed front by an average of 8.5 meters, and even 20 to 30 meters in some places, resulted in a change of the wave activity. Breakers developed at the front, which, together with floatage, resulted in the reeds snapping off and erosion on the shoreline (s. WILMANNS 1998).

The essential features of this factor analysis of a single area, even when it includes a variety of habitats, can be projected onto other areas; the weakness and devitalization of the sprouting plants and the mechanical damage in the summer has proven to be a decisive factor, regardless of whether it results from the weather conditions, from boating and excessive wash, compounded by eutrophication-related floatage of green algae (*Cladophora glomerata* agg.). Are there any measures, which are able to effect a regeneration of the reed belts - with the exception of the rather unrealistic suggestion made to reduce boating traffic in general? Mechanical mowing in the winter proved to be counterproductive, because it bruised the rhizomes and tips of the shoots and further impaired the reeds' vitality. Stone packages and breakwaters (double rows of poles with faggots, i.e. bundles of brushwood) create a zone with less wave formation and encourage

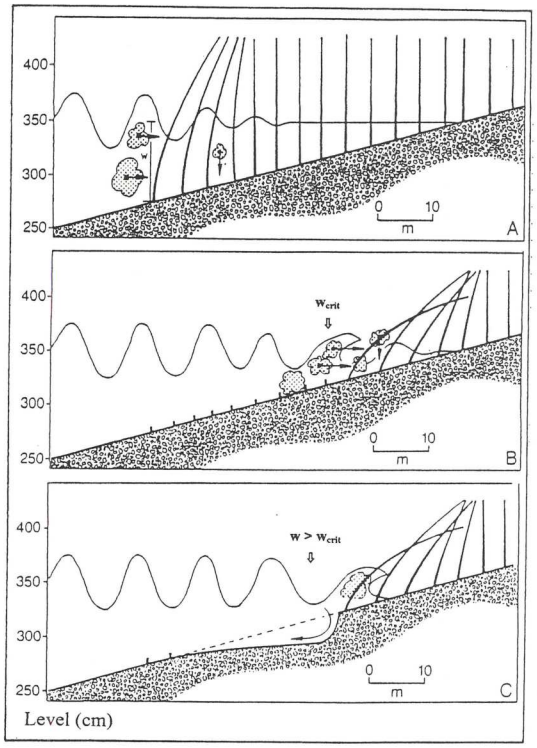


Fig. 20 Consequence of the reed decrease at the Bodensee 1965 until 1967 on shore erosion and mechanical load of the seaward reed belt; A-before the reed decrease, B-after the reed decrease, C-after the ensued surface- and cliff erosion. W-water level, Wcrit-water level, where the shore waves are breaking, dotted-algal blooms (*Cladophora glomerata*) and flow of materials (modified from OSTENDORP 1990).

sedimentation. The cultivation of living plants must also be implemented: either in the form of individual plants with rhizomatous balls or larger coconut fiber mats with a network of roots. In any case, it is essential that a self-imposed limitation is made on water sports and swimming - the pressure put on the recreational landscape is a threat to its very survival.

A new coastal research project: Environmentally compatible groundwater management in areas of the Northsea coast sensitive to hydrogeological and ecological effects

In the area of the Northsea coast between the Netherlands and Denmark (fig. 1) one of the world's most unique habitat has developed: the waddensea with its islands. Formation and dynamics of this landscape depend on a steady transformation by tides, by wind, by estuaries, but mainly by anthropogenic effects (PETERS & POTT 1999).

The exclusivness of this extensive natural coastal landscape was and is the basis for the tourism, which is at the same time the most important source of income for the native population. Because of the tourism it is necessary that drinking water must be supplied in seasonal different intensity. This causes a various claim of drinking water and can lead potentially to an interest

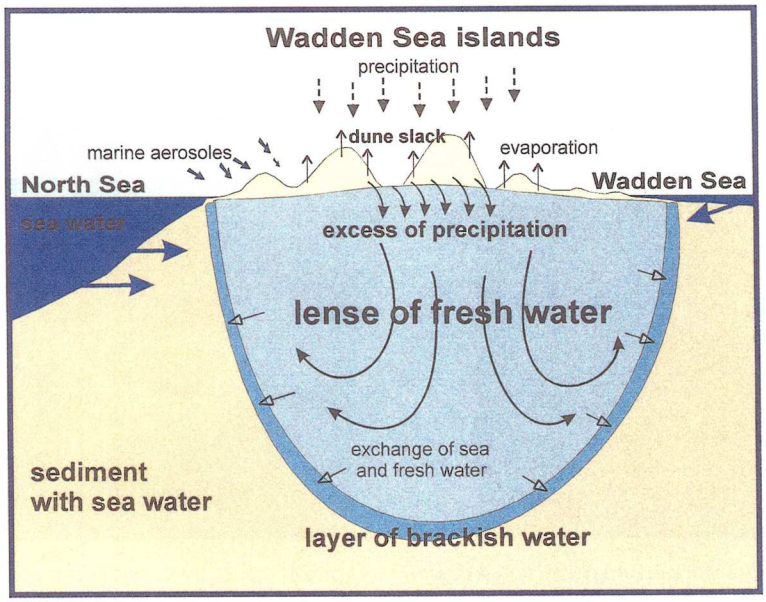


Fig. 21 Scheme of a Wadden Sea island with the fresh water lense surrounded by the seawater (from PETERSEN 1999).

overlapping with the national park waddensea.

Corresponding to the geological set-up of the underground a fresh water lens on the waddensea islands developed. At this the fresh water is carried by the specifically heavier seawater. The groundwater level depends on the one hand on the raised amounts of water, which causes a decrease of the upper groundwater level and on the other hand on the quantitiy of precipitation which causes a rise of the groundwater level (s. fig. 3 and 21). An evironmentally compatible, lasting groundwater management must be determined by the natural water circulation and by the natural recharge of groundwater on each island.

The complex interactions of abiotic factors (climate, soil, hydrogeology, tides) and biotic factors (flora, fauna) lead to the development of typical coastal and dune slack ecosystems, which are particularly sensitive against any foreign effects. Dune slacks are a unique type of coastal ecosystems, a very sensitive, extremely rare and threatened biotop (fig. 3). These moist vegetation of dune slacks like *Littorelletea-, Oxycocco-Sphagnetea-, Scheuchzerio-Caricetea nigrae* and *Phragmitetea*-plant communities depend on the groundwater level and can survive fluctuations of the groundwater level only in a range of tolerance which is charateristic for each vegetation unit (fig. 4). When organic soil layers are drained high amounts of ammonium and nitrate occur by the increased mineralization. Then the rare and typical dune slack vegetation can be replaced by nitrophilus, competetive plants now finding optimal growing conditions and the Reed beds of the dune slacks are decreasing (figs. 4 and 7).

Intensive production of groundwater as an anthropogenic impact but also geogenic threats must be correctly evaluated, specifically for each ecosystem according to possible endangerings of the groundwater and of the biotops of the national park which need protection. In addition detailed and complex hydrogeological, plant sociological and plant ecological investigations are required as well in the field as in the laboratory. For this plant species are marvellous bioindicators for the groundwater level, the water regime of the dune slacks and for the island and

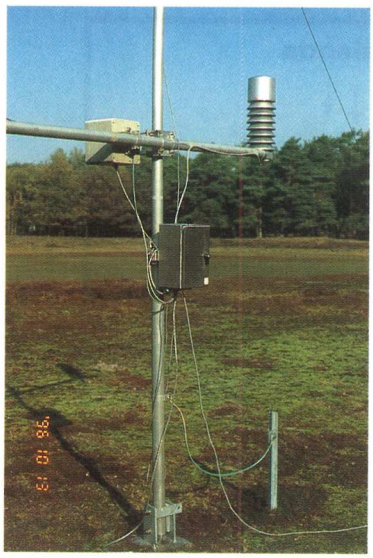


Fig. 22 Datalogger for automatical registration of aerosol-deposition in the air.



Fig. 23 Multilevel-well for registration and recording deep drinking water levels.

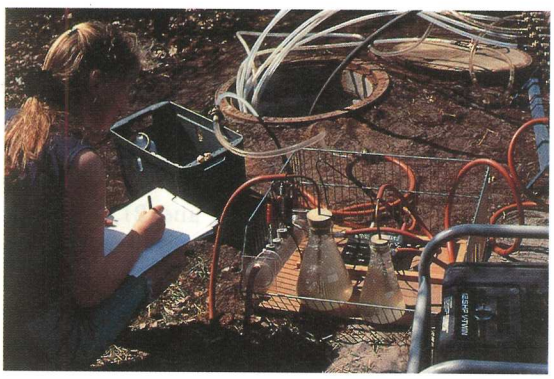


Fig. 24 Measuring instrument at the multilevel-well for registration of water quality.

the coastal landscape at all.

The aim of the planned investigation is a practicable conception for a durable, environmentally compatible groundwater- and soil management considering natural capacities of the coastal landscape (s. figs. 22-24). All natural lakes in the northwestern European Pleistocene sandy landscapes are subjected to a progressive accumulation of nutrients. This is indicated in changes of litoral vegetation in general and especially in Reed bed dune slacks with an increase of electrolytes in the groundwater and the dune slacks themselves.

Water eutrophication is a natural process, which advances gradually. But today, anthropogenic factors add considerably to the acceleration of this process. The monitoring of water ecological conditions, made on the basis of standard investigation methods (s. figs. 22-24), which in turn determines the acceleration of the eutrophication as a result of natural and man made processes (s. POTT 1998b). For the protected areas and their boundary region critcal levels and ranges of

tolerance for example lowest, highest and optimal values shall be worked out which allow a regulation of the groundwater- and soil-management on a long-term basis specifically for each habitat, especially for the highly endangered Reed bed vegetation of dunes lacks.

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