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Reed bed characteristics and significance of reeds in landscape ecology

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Abstract

Reedswamps meet three important functions in landscape ecology: They act as a structural element and as a food-plant for a highly specialized fauna (species protection), the rhizomes stabilize the sediment and the stalks dissipate the wave energy (shore protection), and they improve the conditions for an enhanced microbial decomposition of an external organic load and an elimination or fixation of nutrients (pollution control). Additionally, very large reeds can influence the ground water economy and the local climate. These functions are fulfilled to a high quality only by the common reed (*Phragmites australis* [Cav.] Trin. ex Steud.), depending on the vitality, the fitness for the habitat, stability in space and time, area, and diversification of the structural properties of the stand.

Kurzfassung

Die landschaftsökologische Bedeutung der Röhrichte

Röhrichtbestände erfüllen drei wichtige landschaftsökologische Funktionen: Strukturelement und Nahrungspflanze für eine hochspezialisierte Fauna (Artenschutzfunktion), Festigung des Substrats durch Rhizome und Wellendämpfung durch Halme (Uferschutzfunktion) und Förderung des mikrobiellen Abbaus organischer Substanzen und der Eliminierung bzw. Fixierung von Nährstoffen in der Rhizosphäre (Gewässerreinhaltefunktion). Eine weitere Funktion sehr ausgedehnter Röhrichte besteht in der Beeinflussung des Grundwasserhaushaltes und des Lokalklimas. Diese Funktionen werden in besonderer Qualität von Beständen des Gemeinen Schilfs (*Phragmites australis* [Cav.] Trin. ex Steud.) wahrgenommen. Im einzelnen hängt die Eignung zur Erfüllung einer bestimmten landschaftsökologischen Funktion von der Vitalität des Bestandes, der standörtlichen Eignung, der raumzeitlichen Stabilität, der Flächengröße und von der strukturellen Diversifizierung ab.

1 Introduction

Reeds or reed-like helophyte communities are widespread in the wet places of the temperate holarctis. In most cases they consist of more or less pure stands of the common reed (*Phragmites australis* (Cav.) Trin. ex Steud., Poaceae). *Phragmites* colonizes a wide range of

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habitats, provided that the deep lying rhizomes can reach the ground water table (Rodewald-Rudescu 1974).

In the last decades, however, a decline of fringing reeds became evident at many European lakeshores (Ostendorp 1989). Consequently the belief developed that lakeshore ecotones have to be protected and reed beds should be re-established where they have died back. While working out such a protection philosophy one has to recognize that the rôle of reeds in landscape ecology has not been thouroughly discussed yet. The significance of the reed's stand structure for e.g. reed inhabiting arthropods, fishes, amphibian and bird life is not well known. Hence, it is difficult to formulate criteria of how lakeshore restoration works should be designed and carried out to meet the function of reeds, e.g. in species protection.

The objective of this paper is to give an idea of the most important functions of reed beds in landscape ecology and to present an overview of the reed bed characteristics that are needed to meet these functions.

2 Reed beds in landscape ecology

The main benefits of reeds to landscape ecology may be scheduled as:

a) **species protection**: The *Phragmites* plant acts as a food plant and as an inevitable structural frame for the life of a highly specialized fauna (Ostendorp 1993).
b) **bank protection**: The flexible *Phragmites* stalks dissipate the wave energy and decelerate the nearshore currents (Bonham 1983, Meissner and Ostendorp 1988), the extensive root system holds the substrate together. The suitability of the common reed has been appreciated in biological engineering since the middle of the last century (Holland 1841, Bittmann 1953, 1968).
c) **pollution control**: Full scale experiments with artificial reed beds for waste water purification have demonstrated that the *Phragmites* plant improves the microbial conditions in its rhizosphere under which nutrients can be immobilized or eliminated from the plant/soil-system and an organic load can be decomposed (for an overview of recent work see Hammer 1989, Etnier and Guterstam 1991). Such benefits can also be assumed for reeds at natural stands, e.g. for the purification of non-point runoff from agricultural surfaces. By this means an important part of the total nutrient load to a lake may be checked by its reed belt. The extent of water exchange between the open lake and the reed belt was found to be too low to ensure any significant purification effect (Ostendorp 1988).
d) **atmospheric humidity and groundwater economy**: Vast reed beds may have an impact on the regional atmospheric humidity and temperature due to their evapotranspiration. However, the evapotranspiration of a wetland on a yearly basis is roughly equal to the evaporation rate of a lake's surface (Linacre 1976, Roulet and Woo 1986). The type of vegetation (*Phragmites*, *Typha*, *Carex*, etc.) is not an important factor in water loss (Bernatowicz et al. 1976). Whether the watertable can be lowered by the extensive root and rhizome system of *Phragmites* has not been investigated yet. This topic is not discussed in this text.

The functions of *Phragmites*-reeds cannot be substituted by other types of helophytic vegetation:

- *Phragmites australis* is by far the most important helophyte species in bank protection. It tolerates higher flooding than willows and most of other herbaceous marsh plants, and it withstands mechanical load by drifting matter better than *Typha* (reedmace) and *Schoenoplectus lacustris* (common bulrush). In contrast to *Typha* and *Schoenoplectus* the stalks of *Phragmites* are stout enough to fulfill this work even in winter when they are dead.

- In the function of species protection *Phragmites australis* is irreplaceable. Many phytophagous species and breeding birds depend exclusively on this species. Only few species are bound to other helophyte species (e.g. moustached warbler [*Acrocephalus melanopogon*]: *Typha*-stands; the insect fauna has not been investigated, but see Waitzbauer 1976).
- For the water pollution control, other nitrophilic marsh plants may be on a par with *Phragmites*; however, if the waste water is conducted below ground, *Phragmites* is the only species that can enlarge the depth of the effective purification zone by its deep lying roots and rhizomes.

3 Properties of reed beds

3.1 Stand structure and fitness of the reed stand

Phragmites australis covers a wide range of wet habitats. Depending on the position of the water table one can distinguish between «submerged reeds» which are flooded for at least some months of the season, and «terrestrial reeds» where the water table lies below the ground for most of the time. The submerged reeds can be characterized as a (nearly) monospecific *Phragmites* stand. The terrestrial reed is often rich in attendant helophytes and other wetland species, though *Phragmites* remains dominant (Toth and Szabo 1961, Balatova-Tulackova 1963, Krausch 1965a, 1965b, Weisser 1970, Hilbig 1971). In many cases the terrestrial reed is not a natural part of the landscape but nothing more than a replacement for the natural vegetation, initiated by a more or less continuous human impact on the former vegetation, or a plant cover of entirely man made habitats. *Phragmites* reaches its best vitality and highest biomass production in submerged and monospecific stands. Here its competitive faculty is greatest, supressing other helophytes by shading them out.

Within the group of the flooded monospecific reeds the vitality can be estimated by measuring stalk density, percentage of stalk classes (primary shoots, secondary shoots; Ostendorp and Möller 1990) and the average stem diameter. Undisturbed *Phragmites* stands tend to realize their maximum biomass production (1.5–2.5 kg dry matter m^{-2} y^{-1}, aboveground standing crop) with a minimum stalk density (n = 20–30 stalks m^{-2}). The single shoots are then very stout (up to 15 mm in diameter at the base, up to 5 m tall, panicle included). The vitality of such a stand can be rated higher than a dense stand with slender stalks. However, quantitative statements on ‹optimum› stalk densities cannot be made, as both parameters strongly depend on environmental factors (water table, nutrient supply, mechanical damage, management, etc.).

The percentage of stalk classes (primary [= panicle bearing] shoots, shoots with insect infestion, secondary [= replacement] shoots) gives a quick criterium for the vitality in field measurements. High values of panicle bearing shoots point to fair conditions, whereas stressed stands often exhibit an increased proportion of insect infested shoots (due to drought) or high numbers of secondary shoots (due to mechanical damage or disturbance by grazing, late frosts, etc.) (Haslam 1969a, 1969b).

3.2 Stability in space and time

The stability of reeds over decades or even centuries is reflected in the fact that lakeshore reeds in Central Europe belong to the natural vegetation (e.g. Lang 1990). Similar to climax phytocoenoses, the biomass production, species diversity and niche distribution are time independent. The widely branched rhizome system is the basis of this stability. Its older parts continually die down, and the younger parts branch anew and sprout emergent stalks. The whole interconnected rhizome system (polycorm) seems to be able to exist for millenia (Rodewald-Rudescu 1974: 60). The conditions for stability are destroyed where

(a) a change in climate from dampness to dryness, or the natural succession following the accumulation of *Phragmites*-peat, lead to a reduced flooding depth and at last to a reduction of the (ground-) water supply.

(b) human impact on landscape ecology (manipulation of lake level, construction of shore protection works, management of lakeshore vegetation, introduction of extraneous animal species) changes the environmental conditions.

The last mentioned factors have led to an extensive dieback at many Central European lakeshores (Ostendorp 1989). Even the succession, for example, from a monospecific reed stand to an alder carr, which seems, at first glance, to be natural, cannot be regarded as being independent from man's activities since the Bronze Age.

The stability of reeds in space and time is an important feature for many reed-inhabiting animals: imagines of phytophagous insects are not good flyers; so, sexual reproduction and oviposition takes place in the neighbourhood of the living space of the preceding generation (Mook and Bruggemann 1968, Chvala et al. 1974, Skuhrava and Skuhravy 1981, Tscharntke 1986). Nestlings of the great reed warbler (*Acrocephalus scirpaceus*) are assumed to be imprinted to their habitat, and they return from their wintering locations to the place where they grew up (Catchpole 1972). The parallel evolution of *Phragmites* and the monophagous arthropods feeding on it may give an idea of the constancy of reeds through geologic periods (Hantke 1978–1983). The stability is of great importance for the bank protection function, as the die-back of a reed belt can lead to an irreversible erosion preventing helophytes from recolonizing. Then there is the danger of solid embankments destroying any chances for the development of a natural zonation of waterplants.

3.3 Stand area

In order to adequately meet a given function in landscape ecology a reed stand should not fall short of a minimum area. This minimum size, however, depends on stand structure and external circumstances.

The efficiency as a wave energy dissipator depends also on (I) wave energy density along the reed front, (II) water level above ground, (III) stalk density, (IV) slope and (V) bottom roughness factor (friction by reed stubbles and litter). The minimum width can be estimated from results of Bonham (1983: a 60–75% energy reduction by *Phragmites*-belts of 2 m width, and with a mean stalk density of 100–206 m^{-2}) and own observations at Lake Constance-Untersee (complete wave attenuation by reeds 30 m in width, 18–25 stalks m^{-2}). Theoretical models and field measurements are lacking (but see Meissner and Ostendorp 1988, Binz-Reist 1989).

The factors influencing the efficiency of purifying seepage from organic compounds and nutrients have been intensively investigated in helophyte wastewater treatment plants. The results show that the more important factors are

(a) the hydraulic conditions (above ground or below ground flow, hydraulic gradient, hydraulic load, depth of the porous layer)

(b) the stand structure as an indicator of biomass production and root density,

(c) the hydraulic and chemical properties of the porous layer (hydraulic conductibility, pH-value, grain size, phosphorus adsorption capacity)

(d) the quality (concentration and decomposibility of the organic fraction, concentration and form of chemical bond of nutrients), pretreatment (mechanical, or mechanical plus biological purification) and mean detention time of the wastewater.

Normally, artificial wetlands with helophytes work with purification stretches of 10 to 50 m in length to give sufficiently clean water in the outlet (EUD 1987, NN 1987). Though in natural reeds the hydraulic load and the concentration of pollutants is lower, the purification efficiency can be low, since the mean detention time is reduced when the water finds its way along ditches and surface depressions. Hence, it is reasonable to assume a minimum width of a reed stand for pollution control of c. 10 to 50 m. Lenz (1990) proposes the protection of sensitive habitats from nutrient enrichment by a girdle of reed bed plantations, but details and dimensions are not given.

It is not easy to give a minimum area for the species protection function. The area is only one factor in a multiplicity of stand characteristics which allow a given species to occupy this habitat. Evidently, the minimum area must vary with species. For *Phragmites*-phytophagous arthropods the area seems to be of minor importance, and the morphological and physiological properties of a single shoot make all the difference. This means that even small stands will be occupied. The same seems to be valid for arthropods overwintering in the lumen of reed stubbles. Additionally, the abundance of species in small isolated stands depends on the immigration rate, and so is a function of the distance from larger and more appropriate reed areas.

The great number of reed-breeding bird species is flexible in relation to the size of their nesting habitats. As an example, in the reed warbler (*Acrocephalus scirpaceus*) (Ölschlegel 1981) and in the coot (*Fulica atra*) the breeding pair density increases with decreasing area of the habitat. Some species tend to breed in colonies (reed warbler, bearded tit [*Panurus biarmicus*], and others), so it is difficult to calculate a minimum area for a nesting place. The intraspecific competition for nourishment which is partially the reason for scattered breeding, is lowered in those colony breeders that find their food at a greater distance from their nesting places, e.g. near the lake/reed belt-borderline (great reed warbler, bearded tit) or outside the reed belt (great crested grebe [*Podiceps cristatus*]). They are therefore able to accept smaller nesting habitats. In the case of the purple heron (*Ardea purpurea*) and the little bittern (*Ixobrychus minutus*) breeding habitats and feeding places are broadly identical, and even these species exhibit clustered nesting. It is concluded that the effective area of a reed stand is of minor importance, provided that the other prerequisites for breeding are well developed. Great reed warblers, reed warblers, water rails (*Rallus aquaticus*), coots and others settle for only 0.01 to 0.1 hectare, and for the spotted crake (*Porzana porzana*), the little crake (*Porzana parva*), great crested grebe, little bittern, marsh harrier (*Circus aeruginosus*) c. 0.1 to 1 hectare is sufficient. Only the purple heron and the bittern (*Botaurus stellaris*) need large areas of reeds of c. 1 to 10 hectares (Bauer and Glutz von Blotzheim 1966, Glutz von Blotzheim et al. 1971, 1973, Ölschlegel 1971, Melde 1973, Wawrzyniak 1986, Schiess 1990). Altogether, the density of individuals and the species diversity are positively correlated with the size of the reed habitat (Schiess 1990).

Similarly, the reed area size seems to be unimportant for reed dwelling mammals like the water vole (*Arvicola terrestris*) and muskrat (*Ondatra zibethicus*).

3.4 Additional structural qualities and structural diversification

The lack of other higher plant species in lakeshore reed belts implies their uniformity of structure. The structural properties of a typical fringing reed can be summarized as

a) monolayer architecture of the canopy,
b) dominance of vertical structure elements,
c) dominance of only one vegetal stature (graminoid type),
d) feeble lateral gradients of structural properties (at most along the axis vertical to the shoreline),
e) more marked vertical gradients,
f) uniformity of ontogeny and age of a shoot population.

Such a reed stand is a somewhat extreme habitat, characterized by low species diversity and special adaptations, particularly in reed dwelling birds and phytophagous arthopods (but not so in the detrivore fauna!). These structural properties are utilized in different manners:

(1) screening from enemy vision: the vertical architecture of reed vegetation offers good cover from predators at ground level. This type of architecture, however, does not shelter nestlings and parents from detection by flying enemies (marsh harrier, crows). Therefore, some species mask the upper side of their nests by pulling *Phragmites* shoots over them like a hood (little crake, water rail, coot, bearded tit) (Glutz von Blotzheim et al. 1973, Wawrzyniak 1986: 97).

(2) predator-free space on the stalk: Some species fix their nests exclusively on vertical stalks (harvest-mouse [*Micromys minutus*], great reed warbler, reed warbler); presumably the canopy provides a secure place, because most of the predators cannot climb up due to the limited strength of the stalks.

(3) predator-proof accomodation within the stalk: most of the reed dwelling phytophagous insect larvae live endophagous. Some of them are gall formers (*Lipara* sp., Chloropidae, Dipt.; *Giraudiella inclusa*, Cecidomyiidae, Dipt.); others like larvae and pupae of stem-boring butterfly species live in the lumen of *Phragmites* stalks, invisible and beyond the reach of their enemies for most of the year. Additionally, the soft inner parenchyma of the stem is a far more digestible food than the epidermis tissue with its silica incrustations.

(4) preference of stalks of particular thickness: many species of the reed fauna favour stands in which the stalks have a certain diameter for different reasons:

- The stalk stability, needed to support their body-weights, is reached above a certain diameter (*Phragmites*-stalks as supporting elements for nests: great reed warbler, reed warbler, harvest-mouse; stalks as a perch: great reed warbler).
- The stalk diameter must suit the proportions of parts of the body (harvest-mouse: length of the inner toe; *Archanara geminipunctata* [Noctuidae, Lepidopt.]: body width of the last larval stage; arthropods overwintering in *Phragmites*-stubbles: body width; Piechocki 1958, Mook 1971, Frömel 1980, Vogel 1984, Tscharntke 1990).
- The stalk diameter can be regarded as a measure of the vitality of a stalk. Stout stalks contain more silica, so their resistance to herbivore attack is greater. This could be the reason why some endophagous and gall-forming insects prefer thin shoots, though their nutritional value is less (Mook 1967, Frömel 1980, Tscharntke 1988). However, the interrelations between reproduction rate of phytophagous insects and stem diameter is complex, because the rate of parasitization and predation (e.g. hacking of blue tits [*Parus coeruleus*] to open the stem wall) depends also on stem thickness (Mook 1967, Frömel 1980).

(5) Dense reeds are microclimatically favoured resting and sleeping places for swallows (*Hirundo rustica*), house martins (*Delichon urbica*), white wagtails (*Motacilla alba*), blue-headed wagtails (*M. flava*) and others (Bussmann 1979, Einstein in Frömel and Hölzinger 1987: 467).

Additional structural properties are necessary for many species to give an optimum habitat:

(1) flooding: important, of course, for fish like the eel (*Anguilla anguilla*) as well as for those waterfowl and mammals that reach their nests by swimming (great crested grebe, muskrat).

(2) dead stalks: the abundance of dead *Phragmites*-stalks from the previous year are a decisive factor for reed breeding bird species because their breeding period begins early in the season when the new shoots have not grown up. The young stalks themselves give ground breeding birds no cover, and are too weak and flexible for anchoring nests (great reed warbler, reed warbler). Normally, reeds comprise up to three generations of dead stalks, which gradually break down to form the litter layer, and finally the humic topsoil. Reeds that are mown or burned in winter lack dead stalks, and are not accepted for nesting by many reed breeding bird species (bearded tit, great reed warbler, Savi's warbler [*Locustella luscinioides*], little grebe [*Podiceps ruficollis*], little crake, water rail, marsh harrier, etc.). The reed warbler and the sedge warbler (*Acrocephalus schoenobanus*) settle in winter-mown stands only for their second brood. Sometimes cleared places are used by ground-breeding species typical for open grass habitats but not for helophyte vegetation (blue-headed wagtail, lapwing [*Vanellus vanellus*]) (Ostendorp 1993).

(3) layer of broken stalks: important for birds moving by climbing or hopping, e.g. Savi's warbler, water rail, little crake.

(4) pieces of open water nearby: important for all swimming breeding birds, e.g. great crested grebe, black-necked grebe (*Podiceps nigricollis*) and for those song-birds that feed on big insects (great reed warbler: Bussmann 1979, Dyrcz 1979): butterflies, dragonflies, and beetles are more abundant at the reed/water borderline than in closed reed stands.

(5) open stalks and stubbles: important as hiding places for overwintering arthropods (spiders, beetles, etc.) (Palmen 1948, Tischler 1973, Frömel 1980). The tubular, closed *Phragmites*-stems have been opened either by picking blue tits which feed on endophagous insect larvae and pupae, by mechanical injury to the stalks (drifting matter, ice drift), or by winter mowing and burning.

It is generally accepted that the opening-up of dense and monotonous reeds creates niches which can be occupied by more species than formerly. One example is the ‹edge effect›, created for instance by the prolongation of the reed/water borderline with bights, aisles, and small reed isles. The ‹edge effect› leads to an increase of many reed dwelling animals (*Hyalopterus pruni* [Aphididae, Homoptera], tree-frog [*Hyla arborea*], purple heron, little bittern, marsh harrier, Savi's warbler, reed warbler, great reed warbler, and others) (Mahler 1979, Ölschlegel 1981: 360–361, Grillitsch and Grillitsch 1985, Tscharntke 1989). Even duck species, searching food in the sublittoral, feel at home in the shelter of a diversified reed/water borderline (Reichholf 1970, Cooke 1976).

3.5 Incompatibility of properties

Phragmites plants, as well as reed stands, vary widely with respect to nearly all their properties. But the characteristics do not vary independently. Concisely spoken, all indications of high stability, biomass production and vitality are in marked contrast with structural variety, niche multiplicity, and species diversity. Hence, a given reed stand cannot satisfy all requirements (Tab. 1).

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
stalk diameter	(1)		⊕	⊖	⊕	⊖	⊕						⊖	⊖	⊖	⊖
stalk length	(2)			⊖	⊕	⊖	⊕						⊖	⊖	⊖	⊖
stalk density	(3)				⊖	⊖	⊖	⊖		⊕	⊕	⊕	⊕	⊖		
ratio of panicle bearing shoots	(4)					⊖	⊕	⊖	⊖				⊖	⊖	⊖	⊖
proportion of accessory helophytic vegetation	(5)						⊖	⊕				⊖		⊕	⊕	⊕
water table (below or above ground)	(6)										⊖	⊖				
degree of patchyness within the reedswamp	(7)													⊕	⊕	⊕
unevenness of the waterside edge	(8)													⊕		⊕
abundance of dead stalks from the previous season	(9)										⊕	⊖		⊖	⊖	⊕
thickness of the litter layer	(10)											⊕			⊖	⊕
abundance of open stubbles	(11)														⊕	
load with waste water or sludge	(12)															
mechanical load (waves, drifting matter, treading)	(13)															
winter mowing, winter burning	(14)															⊖
abundance of niches	(15)															

Tab. 1: Review of stand structure properties and influencing factors that normally are positively or negatively correlated

4 Conclusions

Tab. 2 shows in a condensed form the essential results from the discussion above. A ‹+› indicates that the given stand characteristic normally implies positive consequences for the function in question, i.e. an improvement of the reeds' function in shore protection, for example, or an increase of the abundance of the taxon in question. ‹-› relations are not indicated for purposes of clarity. In many cases the characteristics are of no significance to a function or to a taxon, or its consequence has not been well examined. Tab. 2 must be regarded as schematic, being far from true in every case. Much work has to be done to take a second look to the interrelations indicated here, and to fill the gaps.

At first glance, we see an erratic distribution of the ‹+›-marks. This indicates that a simple one-dimensional valuation scheme, e.g. in the form of ordinal scaled classes, does not exist. Nevertheless, we can draw some general conclusions:

(1) the value of littoral or riverine reeds is higher than that of terrestrial reeds; this is especially valid for the species conservation function, whereas for the pollution control function details are unknown.

(2) reeds with open water places can be valued higher than large closed reeds,

(3) reedbeds, flooded to a depth of some decimeters, for at least some months in the season, are ranked higher than unflooded beds with a water table below ground,

(4) abundant dead stalks from the previous year's generation are beneficial for the bank protection function as well as for the species conservation function.

Another group of stand properties, like biomass production of *Phragmites*, percentage of panicle bearing shoots (as a vitality indicator), temporal dynamics of the stand, form of the lakeside edge, are of a different significance. The bank erosion control function profits from closed, homogenous stands with an uniformly shaped lakeside edge, whereas many birds and arthropods prefer weakened and opened reeds with other helophytes in high proportion and with a ragged edge.

Human activities (water table manipulations, recreational activities, waste water discharge, motor boat traffic, etc.) and the cessation of the traditional use of landscape resources (clearing of lakeshore scrubs, mowing of wet grassland and reeds) as well as management techniques for preservation purposes can all change the characteristics of reed swamps. Before planning management measures, the question as to which of the three main functions in landscape ecology is the most important must be answered. The possible consequences for the reed stands should then be considered and compared with the initial objectives of the management philosophy. Shore restoration works often comprise of the enlargement of an existing reedbed or the creation of an entirely new one. Its future properties will largely depend upon the design and the stand structure in turn will influence its potential for species protection, bank erosion control and nutrient retention from diffuse discharge. Hence, limnologists and waterworks engineers have to discover the kind of design which can best achieve the assigned objectives. The results summarised in this paper show the way.

			Stand type		Pieces of water nearby		Biomass ratio of Phragmites australis			Flooding of the stand			Ratio of panicle bearing shoots			
			terrestrial stand	waterside stand	yes	no	more than 90%	50% to 90%	less than 50%	not flooded or episodically flooded	occasionally or regularly flooded	flooded in all seasons	more than 90%	60% to 90%	30% to 60%	less than 30%
SPECIES PROTECTION		stem boring moths (e.g. *Archanara*)	+							+						
SPECIES PROTECTION		apical gall formers (e.g. *Lipara*)	+							+						
SPECIES PROTECTION		stem gall formers (e.g. *Giraudiella*)	+							+						
SPECIES PROTECTION		greenfly *Hyalopterus pruni*														
SPECIES PROTECTION		overwintering arthropods														
SPECIES PROTECTION		fishes		+	+							+				
SPECIES PROTECTION		amphibians			+				+		+					+
SPECIES PROTECTION	reed birds	great reed warbler					+	+		+	+	+	+			
SPECIES PROTECTION	reed birds	reed warbler					+	+		+						
SPECIES PROTECTION	reed birds	Savi's warbler	+								+					
SPECIES PROTECTION	breeding birds	coot		+	+							+				
SPECIES PROTECTION	breeding birds	water rail		+	+					+						
SPECIES PROTECTION	breeding birds	spotted crake		+	+					+						
SPECIES PROTECTION	breeding birds	little crake		+	+							+				
SPECIES PROTECTION	breeding birds	great crested grebe		+	+							+				
SPECIES PROTECTION	breeding birds	black necked grebe		+	+							+				
SPECIES PROTECTION	breeding birds	little bittern		+							+					
SPECIES PROTECTION	breeding birds	bittern		+			+				+		+	+		
SPECIES PROTECTION	breeding birds	purple heron		+							+	+				
SPECIES PROTECTION	breeding birds	marsh harrier		+			+				+		+			
SPECIES PROTECTION		accessory helophytic vegetation	+						+		+					+
SPECIES PROTECTION		accessory palustrine vegetation	+						+	+						+
BANK PROTECTION				+			+					+	+			
NUTRIENT RETENTION										+						

Tab. 2: Tentative synopsis of structure properties that are needed to optimize a given function in landscape ecology.
‹+› – the characteristic implies positive consequences for the function (e.g. increase of breeding pairs of a bird species); empty cells – the characteristic does not affect the function, or implies negative consequences, or the relationship is not sufficiently investigated

Development of the stand			Width of the stand			Area of the stand			Dead stalks from the previous year		Layer of broken stalks and litter		Open stubbles		Waterside edge of the stand	
thinning out, die–back	closed and stable stand	thickening, spreading out	less than 10 m	10 m to 50 m	more than 50 m	less than 0.01 ha	0.01 ha to 1 ha	more than 1 ha	abundant	not abundant	present	not present	not abundant	abundant	evenly shaped, linear	ragged and disintegrated
									+							
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