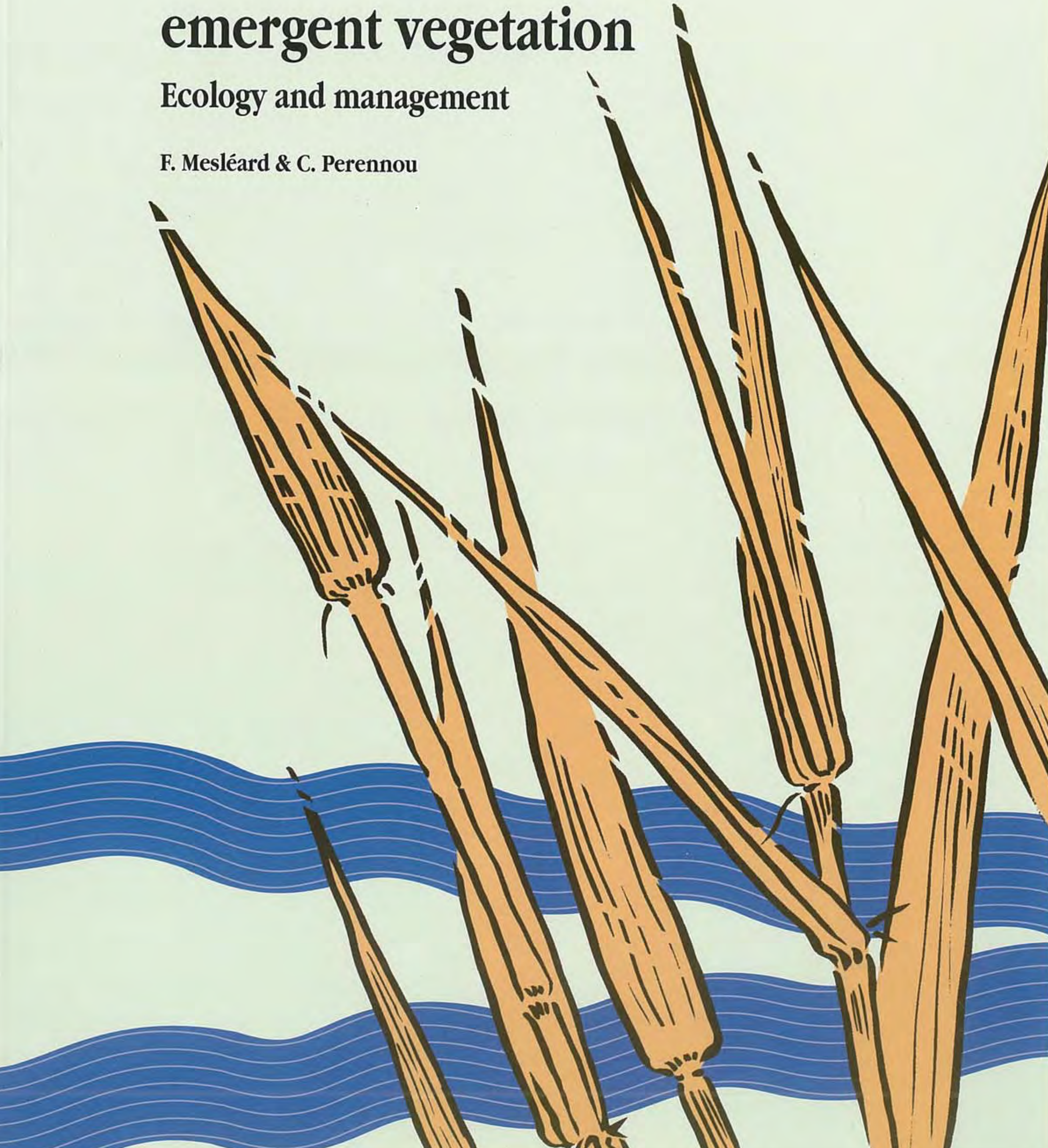
MedWet

Conservation of Mediterranean Wetlands

Aquatic emergent vegetation

Ecology and management

F. Mesléard & C. Perennou



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MedWet

The MedWet action

The Mediterranean basin is rich in wetlands of great ecological, social and economic value. Yet these important natural assets have been considerably degraded or destroyed, mainly during the 20th Century. To stop and reverse this loss, and to ensure the wise use of wetlands throughout the Mediterranean, a concerted long-term collaborative action has been initiated under the name of MedWet.

A three-year preparatory project was launched in late 1992 by the European Commission, the Ramsar Convention on Wetlands of International Importance, the governments of Spain, France, Greece, Italy and Portugal, the World Wide Fund for Nature, Wetlands International and the Station Biologique de la Tour du Valat.

This project focuses on that part of the Mediterranean included within the European Union, with pilot activities in other countries such as Morocco and Tunisia. Two-thirds of the funds are provided by the European Union under the ACNAT programme and the remainder by the other partners.

The concept of MedWet and its importance for the wise use of Mediterranean wetlands was unanimously endorsed by the Kushiro Conference of the Contracting Parties to the Ramsar Convention in June 1993.

The MedWet publication series

Wetlands are complex ecosystems which increasingly require to be managed in order to maintain their wide range of functions and values. The central aim of the MedWet publication series is to improve the understanding of Mediterranean wetlands and to make sound scientific and technical information available to those involved in their management.

François Mesléard and Christian Perennou, 1996
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Titles of the collection :

1. Characteristics of Mediterranean Wetlands
2. Functions and Values of Mediterranean Wetlands
3. Aquaculture in Lagoon and Marine Environments
4. Management of nest sites for Colonial Waterbirds
5. Wetlands and Water resources
6. Aquatic emergent Vegetation, Ecology and Management

Conservation of Mediterranean Wetlands

MedWet

Aquatic emergent vegetation

Ecology and Management

F. Mesléard and C. Perennou

Number 6

Series editors : J. Skinner and A. J. Crivelli


F. Fève / Bios

Preface

Wetlands in the Mediterranean region are of particular importance ecologically. Throughout the year they hold sufficient water to produce high biomass – a productivity unequalled in the terrestrial ecosystems of this region. In addition to this fundamental role as primary producer, the emergent vegetation in wetland areas is of great importance in structuring the landscape and provides, in turn, a habitat and source of food for the rich fauna of this environment. The vegetation is a resource for diverse human activities, can be of considerable conservation value and plays an important role in water purification. Behind the apparent uniformity of the population of large, dominant species, reeds, bulrushes, sedges and glassworts, there is a diversity of species that are endemic to this environment and many are rare and threatened.

As a result, the management of emergent aquatic vegetation needs special attention. Active management is required to maintain the animal and plant diversity which are closely entwined. Traditionally, man has always influenced what are thought of as "natural" wetland habitats by manipulating the water level in order to graze his herds, or by cutting the reeds. Here, like elsewhere, the wetland manager is called on to intervene and orientate the development of the vegetation, or maintain it in the desired state. More than elsewhere, apparently minor changes in management can have major repercussions on the vegetation due to the dynamic nature of this environment and the many interactions between species.

This booklet provides, in simple but precise language, the principles needed to guide the manager, but which are in scattered and often inaccessible scientific and technical publications. This opens horizons for the manager who is required to address many still little-understood fields, such as the interest and risks of using herbicides in aquatic environments, or the worrying problem of invading exotics, which is becoming increasingly acute in wetlands of many countries.

J.P. Henry
Curator
Conservatoire Botanique de Porquerolles, France

Reedmace is easily recognized by its cigar-shaped inflorescence.

Contents

Introduction

Emergent aquatic plants dominate the landscape of many Mediterranean wetlands: the vast reedbeds of common reed or *Scirpus spp.* in deltas and around the edges of freshwater lakes; huge stretches of glasswort on the limits of salt and brackish marshes.

These are the habitats of animal or plant species of high conservation value: large colonies of purple herons in reedbeds, feeding areas for wild boar in the *Scirpus* beds, spawning grounds for fish and amphibians in flooded areas rich in vegetation. These habitats are also sites of numerous human activities such as reed cutting, hunting, grazing and tourism. This is why such areas are of particular interest for managers of protected areas and decision-makers alike.

By definition, emergent aquatic plants are species rooted in soil that is flooded for at least some of the year; part of the plant grows out of the water for part of the growing season; flowers are produced by the aerial shoots, on or above the surface of the water. They therefore differ from rooted submerged plants (e.g. the pondweeds, *Potamogeton spp.*, eel-grass *Zostera spp.*, ditch-grass *Ruppia spp.* etc.) and floating plants (e.g. duckweeds *Lemna spp.*, water fern *Azolla filiculoides*, etc.), whose roots are free in the water.

Grazing has a considerable impact on marsh vegetation in the Mediterranean.

All emergent aquatic plants do not fill an ecological role of the same importance, and will not be treated identically here. Some, due to their size and abundance, make up a habitat which is widely represented in the Mediterranean and essential for other animal and plant species. For example the common reed *Phragmites australis*, sea club-rush *Scirpus maritimus*, reedmace *Typha spp.*, glassworts *Arthrocnemum spp.* and some others. All these species can form large monospecific beds. These species (see table below) are referred to in detail throughout this booklet and each has a detailed technical note in the last section. Water primroses *Ludwigia spp.*, which are introduced species, are included because of their strong impact on wetland ecosystems. They occur in France, and are likely to colonise the rest of the Mediterranean in the medium term.

Other species, less tall and/or generally not dominant, such as yellow flag *Iris pseudacorus*, *Juncus maritimus*, *Cladium maritimus*, *Phalaris arundinacea*, *Lythrum salicaria*, etc., will be used to illustrate different points. These species can, however, cover large areas – e.g. *Juncus maritimus* is the emergent plant which forms the largest communities in the Merja Zerga (Morocco)[1].

The objectives of this book are:

- to provide an understanding of the ecological functioning of systems dominated by emergent aquatic plants;
- to draw together information necessary for decisions on the management of the wetlands around the Mediterranean, which are becoming increasingly artificial;
- to help managers to obtain the desired plant communities, or to control invasive ones;
- in the current context of declining agriculture production in the European Union, to contribute to the debate about possible future uses of former marshes, drained during the height of agricultural production, and to help with the restoration of wetlands.

Reed (or phragmites)	*Phragmites australis*
Sea club-rush	*Scirpus maritimus*
Scirpus littoralis	*Scirpus littoralis*
Bulrush or common club-rush	*Scirpus lacustris*
Reedmaces	*Typha latifolia, T. angustifolia*
Glassworts	*Arthrocnemum fruticosum, A. glaucum ; Salicornia europea, S. radicans*
Water primroses	*Ludwigia grandiflora, L. peploïdes*
Water couch	*Paspalum paspalodes (= P. distichum)*

Main aquatic emergent plants.

1 - Anonymous, 1994

Introduction

The world of conservation often seeks precise, quantitative information on the requirements for, and tolerance to flooding, salinity, nutrients*, etc. for each species. It is important to realise that the information available is of limited generality, and is not necessarily valid throughout the range of the species. For example, the common reed does not normally germinate in soil with a salinity of 29 g/l, however, an ecotype* occurs in Israel of which 70 % of seeds germinate with such a salinity[1]. Similarly the glasswort *Salicornia europea* is reputed to show, according to different authors who worked in different regions, optimal germination* at 0 g/l salinity, or at 15 g/l. Data on the ecology of species must therefore be used with caution; they are the best currently available, but in the absence of wide-ranging and detailed descriptions one cannot be sure that they are representative of conditions in the whole Mediterranean region. Indeed quantitative data on some ecological traits are completely lacking, even for some common species.

Plant communities protected under the Habitats Directive

Annex I of the European Union Habitats Directive lists and protects many plant communities dominated by emergent aquatic plants. Among those found in the Mediterranean region are communities of *Salicornia spp.* and *Arthrocnemum spp.*, great fen sedge *Cladium mariscus* marshes, grasslands of purple moor grass *Molinia caerulea*, and some acid marshes (with *Carex intricata, Scirpus caespitosus).*

Few emergent aquatic plants are by themselves protected by this directive (Annex II and IV), because most of them are, in fact, common. Only the glasswort *Salicornia veneta* and the spike-rush *Eleocharis carniolica* are listed because they are considered rare. Many of the animal species protected by either the Birds Directive (Annex I) or the Habitats Directive (Annexes II and IV) are partly dependent on emergent aquatic plant communities, e.g. European pond tortoise *Emys orbicularis*, pelicans *Pelecanus crispus, P. onocrotalus*, several herons such as *Ardea purpurea* and *Botaurus stellaris* and some dragonflies.

Management must be effective in maintaining these threatened habitats and species. This is one of the primary objectives of the LIFE regulation and the Natura 2000 network which have been developed by the European Community.

1 - *Waisel, 1972*

2 - *For example Médail, 1993 for France*

The emergent vegetation of wetlands

The duration of flooding, its frequency and depth are the principal factors which control the distribution of vegetation within Mediterranean wetlands.

Other factors such as the type of substrate, or the salinity (deltas, edges of lagoons, etc.), the current or the climate (temperature), lead to the presence, or dominance, of characteristic species. Four main habitat types where emergent species are dominant can be distinguished:

- periodically flooded coastal marshes, where the salinity is often the determining factor;
- slightly brackish marshes of delta habitats;
- freshwater marshes;
- wet grasslands, which are the transition zones between marshes and dry land habitat. They may be freshwater (floodplains) or brackish (deltas).

Large expanses of yellow flag iris indicate a marsh of low or no salinity.

Coastal marshes

Coastal marshes, subject to salt and to alternating periods of sometimes long but irregular flooding and drying-out, often have communities with little diversity.

With heavy rain, these communities can be flooded for several months. The vegetation is characterised by a small number of species which tolerate flooding up to 10-20 cm during winter.

In areas where the flooding is most irregular, the plant cover is sparse and the emergent vegetation is composed mostly of annual* species. Glassworts *Salicornia spp.*, seablites *Suaeda spp.* and saltworts *Salsola spp.* develop particularly on soils containing a lot of calcium particles and little organic matter. Where flooding is less irregular, succulent* perennial* plants occur: perennial glassworts *Arthrocnemum fruticosum* and *A. glaucum*; golden samphire *Inula crithmoïdes* and sea purslane *Halimione portulacoïdes* dominate. *A. glaucum* is the most xerophilic and salt-tolerant species, and as salinity increases (> 40 g/l) it dominates *A. fruticosum*. When the length of the flooding period decreases, first *A. fruticosum* and then *Halimione portulacoïdes* become dominant, and other species such as sea aster *Aster tripolium* begin to appear. Golden samphire occurs on the higher ground.

In the middle of tufts of *A. fruticosum* or golden samphire, the accumulation of plant material, together with the elevation of the soil and the relative protection from grazing, allows the growth of grasses

Coastal marshes are strongly influenced by the sea. Khnifiss lagoon, Morocco.

The emergent vegetation of wetlands

J. Roché / Bios

The glasswort is characteristic of coastal wetlands. It is able to survive long summer drought and very high salinity, detectable here by the white efflorescence.

such as *Puccinelia festuciformis* and other non-halophytic species, as they can here avoid the severe conditions of the habitat (flooding and salt).

When flooding is reduced to little or nothing, sea purslane makes up the, often very dense, plant communities. Other species are also frequent: sea lavanders *Limonium ferrulaceum, L. vulgare*, marsh-arrow grass *Triglochin spp.*, rushes *Juncus subulatus, J. maritimus, J. acutus.*

In the centre of small temporary marshes, or around the edge of larger ones, the grass *Aeluropus littoralis* frequently occurs and can rapidly colonise large areas by vegetative reproduction. The tamarisks *Tamarix spp.* and marsh-arrow grass are also frequently found here. Tamarisks often occur in the landscape on the edge of marshes; they can be dense, particularly in deltas. Around the Mediterranean several species of tamarisk occur: *T. canariensis* and *T. africana* in Spain, France and Portugal, *T. tetrandra* in the Balkans, *T. gallica* in France, and *T. aphylla* in North Africa and the Middle East.

Communities of cord-grass *Spartina spp.* have a limited distribution in the Mediterranean. Typical of coasts subject to tides, these communities develop along the Adriatic coast where the impact of the tide is felt, as well as along the Atlantic coast (e.g. Marismas de l'Odiel), in the Ebro Delta, etc.

Brackish marshes of deltas

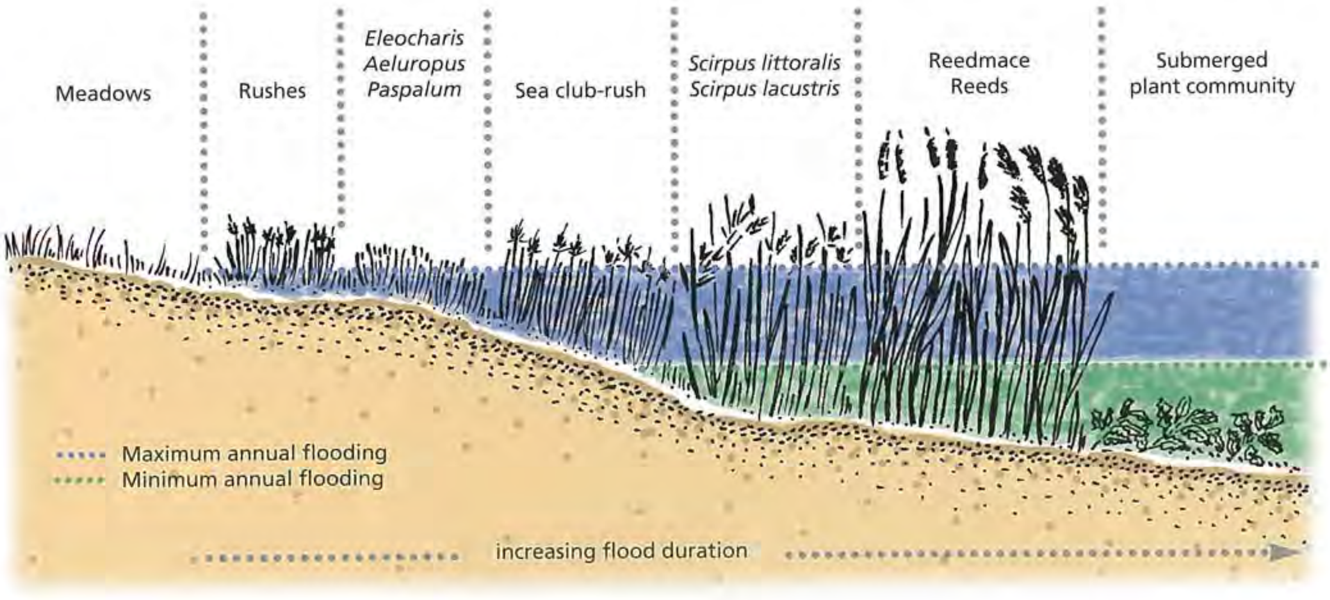
Club-rushes often dominate where the salinity does not go above 5 g/l.

The slightly brackish Mekhada marsh in north-east Algeria (over 5,500 ha) holds one of the largest stretches of *Scirpus maritimus* in the Mediterranean; more than 90% is covered by this species. The common reed covers only a few dozen hectares.

The tall club-rushes *Scirpus lacustris, S. littoralis* are found where flooding is deepest (40-100 cm at the peak of flooding), whereas sea club-rush *Scirpus maritimus* occurs in the intermediary zone between the latter species and the species on the edge of ponds. When the salinity is not high (< 8 -10g/l) and the drying-out period is short, common reed competes strongly with the club-rushes. In this situation, only grazing of the reed allows the club-rushes to develop fully. The sea club-rush then tends to dominate, but smaller species such as *A. littoralis* or the little rushes (salt marsh rush *Juncus gerardi)* often benefit by grazing, which controls the club-rushes, giving them access to the light.

Communities of rushes develop on the extreme fringe of the marshes. The taller species (sea rush *Juncus maritimus*, sharp-rush *J. acutus*) are not preferred by grazing animals, and as a result heavy grazing allows them to develop, at the expense of club-rushes for example. As the height of the land increases and salinity decreases, more terrestrial species, such as salt marsh rush, can develop.

An example of the succession of vegetation: the edge of a brackish marsh in the Camargue.



The emergent vegetation of wetlands

Freshwater marshes

The vegetation of freshwater marshes is often dominated by a few, highly productive species.

Their capacity for growth and vegetative reproduction (the species are often clonal*) makes them very strong competitors, and as a consequence the plant communities are usually not diverse. Common reed, reedmaces and papyrus *Cyperus papyrus* stand out from other species because of their great height.

The papyrus is a tropical and sub tropical species, and is highly localised in the Mediterranean. It is not tolerant of seasonal variations in water levels of more than 2.5 m, nor drying-out. Due to the Aswan dam, which has severely affected the variations in water level, this species has almost disappeared from the lower part of the Nile in Egypt.

The common reed, through vegetative reproduction, has an exceptional capacity to expand into new areas. In one season it can put out stolons* of more than 10 m. Due to its height (2-5 m) it can easily access light and hinder the development of other species. The reedbeds can remain relatively stable over time; seasonal flooding and drying-out favours decomposition of the litter and oxygenation of the soil. This stability is however dependent on certain conditions of the habitat. If the flooding is not deep, or sedimentation* has begun (which gradually reduces the depth of flooding), woody species can colonise the reedbed. Willows *Salix spp.* and alder *Alnus spp.* easily colonise where the soil is always damp. In drier conditions and without grazing, bushy species colonise first, followed by tree species. In the Mediterranean region, the common reed is often the preferred species of the large herbivores, whereas the reedmaces are little eaten. As opportunists this latter species grows when the habitat is not suitable for the common reed: heavy flooding, no drying-out period, and poor water quality. In the coastal zone, the arrival of reedmaces is often correlated to disturbance of the water regime, heavy grazing and trampling, etc.

The other, smaller, emergent plants (bur-reed *Sparganium spp.*, sweet grasses *Glyceria spp.*, flowering-rush *Butomus umbellatus*) are potentially dominant when conditions approach those of wet grasslands (brief flooding, small depth), and where grazing controls the taller emergent plants such as the reed, allowing them access to the light.

In slightly flooded, freshwater habitats, sweet grasses or sea club-rushes can cover large areas. They are then associated with a diverse array of plants: marsh bedstraw *Galium palustre*, water-dropworts

Oenanthes spp., water dock, cyperaceae, mints. A large number of grasses are also found in this habitat, e.g. *Agrostis stolonifera, Cynodon dactylon* and Yorkshire fog *Holcus lanatus.*

In floodplains, oxbow lakes are often dominated by the same species as typical marshes or lake edges: reeds, reedmaces, club-rushes, cyperacea, etc.

The papyrus marshes of Lake Hula, Israel.

One of the last populations of papyrus in the Mediterranean

Until it was drained in 1958, Lake Hula in Israel harboured 1,300 ha of freshwater marsh with papyrus, which was several metres high. It held a rich fauna of reptiles, amphibians, nesting herons, etc. An industry based on papyrus had grown up over the centuries: building of huts, ropes, mats, etc.

Only 120 ha have been saved from drainage. Today the administration wishes to restore as much as possible of the old marshes and the papyrus on the Hula Nature Reserve which now covers 400 ha[1].

1 - See Dimentman et al., 1992

The emergent vegetation of wetlands

Wet grasslands

Wet grasslands are not very common in the Mediterranean region, because the necessary conditions are rarely found: a gentle slope in the draw-down zone and a superficial drying-up only.

To maintain these grasslands the reed and/or the woody species have to be controlled by grazing, cutting or fire. These grasslands are marshes in the process of drying out, or are often reduced to the narrow fringe between the marsh and the unflooded cultivated area. Gramineae, rushes and sedges dominate wet grasslands, the exact composition depending on the length of flooding, the salinity, soil, grazing pressure, etc.

By maintaining water in the marsh until spring, plant communities dominated by flowering rush, spike-rush, yellow flag *Iris pseudacorus* and small rushes are encouraged. In particular, salt marsh rush, relatively tolerant of salt, is often dominant when salt is present. In peaty soils, great fen sedge *Cladium mariscus* can develop dense communities, for example close to resurgences of the water table. Livestock graze only its young shoots. Within great fen sedge communities, species such as gipsy-wort *Lycopus europaeus* and purple loosestrife *Lythrum salicaria* can be found.

In very wet soils, often with organic matter and zero salinity, communities of purple moor-grass *Molinia caerulea* or sedges develop: on the edges of marshes, along water courses and canals, etc. Within the sedges species-rich communities are found: *Carex pseudocyperus, C. paniculata, C. laevigata, C. riparia.* Other characteristic species include purple loosestrife, water-dropwort *Oenanthe lachenalii,* water-crowfoots and bog orchid *Orchis palustris.*

Drier conditions encourage the development of rushes and gramineae, which indicate the transition to grassland communities: blunt-flowered rush *Juncus subnodulosus,* marsh foxtail *Alopecurus geniculatus* or *Agrostis stolonifera.* On poor and well-drained soils the plant communities are essentially made up of small rushes: *Juncus bufonius, J. pygmaeus,* and quillworts such as *Isoetes durieui.*

The adaptation of emergent species

In Mediterranean wetlands emergent plants can be subject to stressful conditions: drought, flooding, freezing, acidity, salinity, etc. These factors can succeed each other or be additive, and they may vary through time and in intensity with alternate periods of flooding and drought, heat and freezing, etc.

Being unable to move, plants have had to develop adaptations to allow them to tolerate these stresses*, or to escape temporary constraints by rapidly completing their life cycle (germination, growth, flowering, ripening of the seeds) during the least unsuitable period.

The first strategy ("struggle") is used by the perennial species, i.e. the majority of aquatic, emergent plants; the objective is to maintain individuals in the long term. The second strategy ("avoidance") is used by the annual species, whose life-cycle is often not longer than a few weeks.

Emergent plants also develop multiple mechanisms for rapid colonisation, thus staving off local extinction: wind dispersal, seed banks, floating seeds, vegetative reproduction, etc.

Reeds can produce more than 1,500 seeds per panicle (seed head). Seeds are small and provide a mean for colonising distant wetlands.

Characteristics of the biology of aquatic plants

Aquatic plants benefit from the temporary presence of unlimited water. Thus, they are often highly productive species.

The dub-rush *Scirpus littoralis* has submerged leaves which photosynthesise directly after germination, and aerial stalks containing chlorophyll which take over when the plant emerges above water.

For growth and reproduction, all plants need:

- gas exchange with the immediate environment, through leaves and/or roots: photosynthesis (absorption of carbon dioxide, release of oxygen) and respiration (the inverse process);
- water, for growth and to balance losses by transpiration. Water is taken up by the roots;
- nutrients (nitrate, phosphate) which they usually obtain from the substrate where they are rooted.

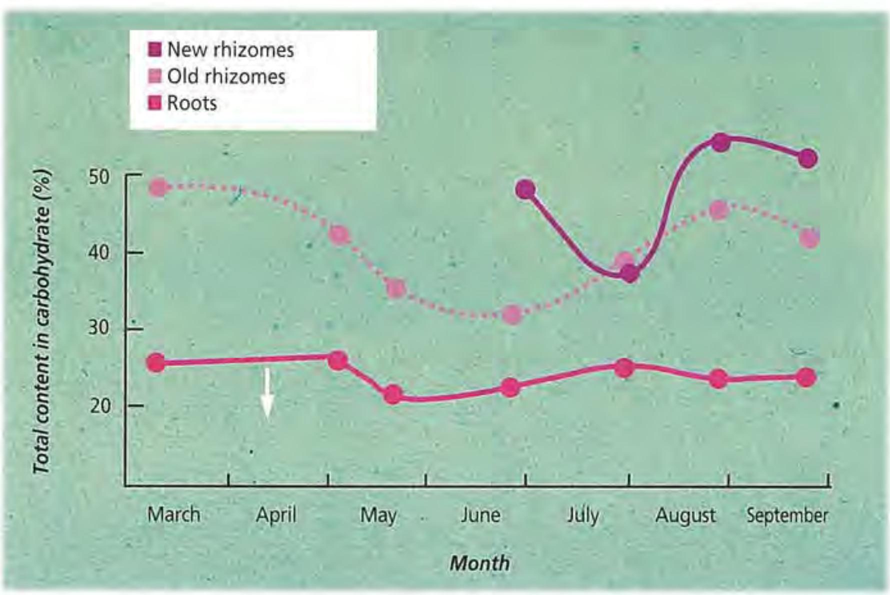
Emergent aquatic plants experience alternate wet and dry periods; each brings certain problems, but resolves others. Emerging above water, these plants have advantages over terrestrial plants with respect to access to light and carbon dioxide and their growth is not limited by lack of water. For this reason they are often very productive: the productivity of the common reed can reach up to 40 tonnes of dry matter/ha/year; papyrus productivity measured in tropical Africa can reach 100 tonnes/ha/year. These are some of the highest productivities found in any of the world's plant communities, comparable to the 60 tonnes/ha/year from irrigated maize fields.

The marshes of the Mekhada in Algeria contain one of the largest beds of sea club-rush in the Mediterranean.

Tubers and rhizomes

Many emergent, aquatic plants are perennial (reedmaces, common reed, club-rushes) with underground organs (rhizomes, tubers) for stocking carbohydrate reserves, which also play an important role in their vegetative reproduction.

The organs allow the plant to resist stress* (rhizomes resist anoxia* better than roots) and thus survive, while reserves are accumulated during the period of maximum photosynthesis, in summer, and ensure the individual plant's survival thereafter. The aerial part of the plants can be destroyed (fire, grazing, cutting), and the following year they grow again from the underground organs. From spring onwards, their reserves are mobilised and used to produce the aerial part of the plant; the sugars in the tubers and rhizomes are used up.



The carbohydrate content of reed rhizomes decreases in spring during growth, then increases again in summer when reserves are being stocked.

After Dykyjova & Kvet, 1978

Resistance to extreme factors in the habitat

Flooding, salinity and drought, independently or together, can cause difficulties for emergent plants. They have developed various mechanisms of resistance or adaptation to these constraints; they may be anatomical, mechanical, physiological or phenological.

The first weeks following germination are a critical period, in which any rapid change in the environment can be lethal for the individuals.

Resistance to drought

Mediterranean wetlands are faced with a seasonal water deficit which is unpredictable but occurs particularly in the summer. As well as this climatic drought, there may also be a water deficit for edaphic* reasons, if for example the soil is well-drained or very mineral. Emergent plants have adaptations to drought which are essentially mechanical. Sea lavenders as well as sea rush have developed resistance mechanisms similar to those found in plants from very dry habitats: regulation of transpiration, thick leaves, etc. Many monocotyledons* in brackish or salt marshes have protective pellicules on their leaves made of wax, or a system of hairs which limit the joint effects of salt and evaporation.

The plant-life of the brackish coastal marshes has been forced to adapt to their annual dehydration.

The adaptation of emergent species

Resistance to flooding

Emergent aquatic plant species show a variable tolerance to the absence of oxygen in the soil: their rhizomes survive for more than a month (yellow flag, common reed, reedmaces) without losing their ability to regenerate, or in some cases up to three months (sea club-rush, bulrush and *Scirpus littoralis*. Club-rushes and reedmaces even manage to grow in these anoxic conditions.

Flooding, during the growing season, can have a range of negative effects on aquatic plants: limitation of soil oxygen; reduction of oxygen exchanges and reduction of light for the submerged leaves; reducing soil conditions which lead to the production of ions which are toxic for the plants (Fe^{2+}, S^{2-}). This reduction process in the soils is characterised by a dark grey colour and the production of hydrogen sulphide gas with its characteristic rotten egg smell, and can be measured on a voltmeter. The measured redox (oxidation reduction) potential is lower (-0.4 to 0.2 volts) than that for an oxygenated soil (0.3 to 0.8 volts).

As a result of these effects, flooding inhibits growth and reproduction of emergent plants, or can even cause their death, thus reducing their density. Confronted with these problems, the fact of being emergent constitutes a major advantage. The aerial leaves enable permanent access to oxygen and light, except when there is competition with taller species and it helps them out-compete submerged plants, whose growth is limited by turbidity in the water.

The tolerance limits of flooding

Lake Kerkini (7,300 ha), a reservoir in northern Greece, had, until 1981, a reedbed of over 500 ha made up of bulrush, common reed and reedmaces. It tolerated an annual flooding of 200-300 days, with a depth of as much as 3.2 m for 1-2 months.

The height of the surrounding dykes was increased, raising the average depth by 2.3 m and the amplitude of the variation in flooding by 1.3 m. In two years the reedbed had completely disappeared, as the water level was now too high for the common reed, and too variable for the bulrush. The reedbed failed to re-establish itself further up the lake edge, apparently because of grazing, which prevented colonisation. However, the wet grasslands of *Paspalum paspalodes*, *Cynodon dactylon*, etc., which had slightly declined in area, continued growing, shifting to slightly higher ground (their lower limit moved 1.7 m upwards). In parallel, white water lilies *Nymphea alba*, which tolerate greater fluctuations in the water level, appeared and today cover hundreds of hectares. A peripheral semi-flooded forest is in chronic decline.

Any modification, man-made or natural, of the water regime of a wetland will be reflected in changes in plant communities and species distribution, associated with their specific tolerance of fluctuating water levels, grazing, etc.

1 - *After Crawford, 1987*
2 - *After Crivelli et al., 1995*

Many halophytic* plants in salt marshes have aerenchymatous* root tissue which is capable of stocking air; this allows them to compensate for the oxygen deficiency in the soil. The aerenchyma also helps in the fight against toxic substances in anaerobic* soils (iron, sulphur): within this tissue, the mechanisms of oxidation of sulphur, or fermentation, neutralise these molecules, and limit self-poisoning.

Several species, such as the reeds and reedmaces, have developed means of transporting air, actively and passively, to the roots.

To compensate for the irregularity and the unpredictability of water regimes in Mediterranean wetlands, many plants have also adapted their life-cycle: e.g. delayed germination in the absence of light, dormancy until particular hydrological conditions are obtained, or physiological dimorphism among the seeds of the same individual (see box below).

An example of a plant with dimorphic* seeds

The glasswort *Salicornia patula*, an annual species, occurs in the transition zone between temporary and permanent flooded areas. The seeds from the centre of the flower do not need light to germinate and are not very sensitive to salinity in the habitat; whereas the seeds from the edge require light, a cold period to germinate, and are very sensitive to the salinity of the habitat. In a very variable Mediterranean climate, the plant can hence germinate in a wide range of ecological conditions, reducing the risk of becoming locally extinct[1].

1 - After Berger, 1985

The adaptation of emergent species

Resistance to salt

The large majority of other plants show poor tolerance to salt. In tolerating salt, without actually needing it, a few species are able to cover large areas due to the lack of competition from other species. Only a very few plants are really stimulated by the presence of salt: for example *Suaeda maritima* grows optimally when the salinity is 10g/l. For most of the emergent species the presence of salt produces two negative effects: toxicity and shortage of water ("physiological drought").

To fight against the toxicity of salt, certain species have salt excretion glands on their leaves (tamarisk, sea lavender, cord grass); other plants like the glassworts and the sea club-rush stock it away in special organs which are shed annually. Succulent plants (glassworts, sea purslanes) stock large quantities of water in their cells which allow the internal concentrations of salt to be diluted.

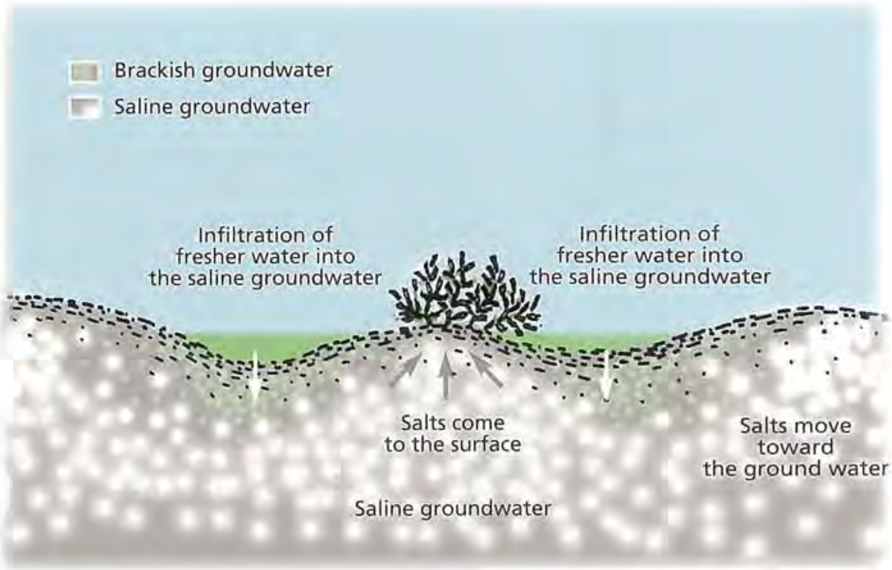
Water is present within reach of the roots, but is difficult for the plant to absorb. It is a principle of physics that water circulates spontaneously from more dilute concentrations (here, the plant) to higher concentrations of salt and/or ions (here, the wetland): the water in the cell therefore has a tendency to leave the plant; this is the opposite of what happens in a freshwater habitat, where the plant is "saltier" than the surrounding habitat. There are many negative consequences for the plant: reduction of respiration and/or the incorporation of nutrients and essential minerals, etc.

The plant must therefore struggle to stop the "losses" of water. There are two possible solutions. Both of them are used by emergent plants and both are costly in energetic terms: actively take up soil water, whose salt concentrations can be toxic for the plant (see above); or raise the internal osmotic* pressure by synthesising large molecules in order to reverse the passive direction of the circulation of water.

J. Roché / Bios

The glasswort's succulent shoots store water which allows it to dilute its internal concentration of salts.

The strategy of avoidance, which is identical to that used by plants in dry habitats, allows annuals to concentrate their growth in the periods when the influence of salt is at its lowest: after the rains which dilute the high concentrations. During the rest of the annual cycle, when conditions are harsher, the plants survive as seeds.



A slightly raised area, which is therefore less often flooded, enables salt to come up to the surface.

The importance of topography

The topography, or rather the microtopography of the land has an important influence on the plant communities which can establish themselves. An elevation of only 5-10 cm can reduce the duration of flooding considerably and increase soil salinity, resulting in a patch of vegetation more halophile* than the rest. With a height of 1-2 m, for example old river levees within deltas, flooding is rare and salinity low or absent, which allows a vegetation typical of temperate freshwater habitats to develop: ash, willow, poplars, etc.

Edaphic factors, nutrients and eutrophication

As emergent aquatic plants are potentially very productive, they require large amounts of nutrients (particularly nitrates and phosphates) and react strongly to habitat changes.

Too many nutrients (eutrophication) within a wetland create problems for aquatic plants; submerged plants are more affected than emergent aquatic plants. The most obvious signs of eutrophication, frequent in Mediterranean lagoons, are hyper eutrophic (or dystrophic) conditions: heavy mortality of the submerged plant communities and aquatic animals, nauseous smells, and decomposing plants accumulated on the edge of the lagoon. These crises can sometimes occur naturally; however, agricultural and domestic pollution increase their frequency and intensity.

Hyper-eutrophic crises arise because of the accumulation of excess nutrients (nitrates, phosphates), which in favourable conditions (heat, no wind, little turnover of the water) allow algae such as *Ulva spp.*, *Chaetomorpha linum*, filamentous algae *Cladophora spp.*, *Spirogyra spp.* or blue-green algae to proliferate.

The consequences for the emergent aquatic plants are numerous:

- monopolisation of the oxygen by the algae, and subsequently the micro-organisms which decompose them when they are dead, prevents survival by all other organisms;
- anoxia in the water column accentuates that in the sediment, which is already a negative factor;
- the algal carpet limits light penetration, and photosynthesis by aquatic plants can cease completely;
- nitrates favour the growth of stems (as in the overuse of nitrates on cereals), making them more likely to break;
- the algae surround the fragile stems, weigh them down and break them, particularly in areas exposed to wind and waves.

In reeds this last point is often the most damaging: water gets into the stem and prevents the movement of oxygen to the roots, which leads to the gradual death of the rhizome.

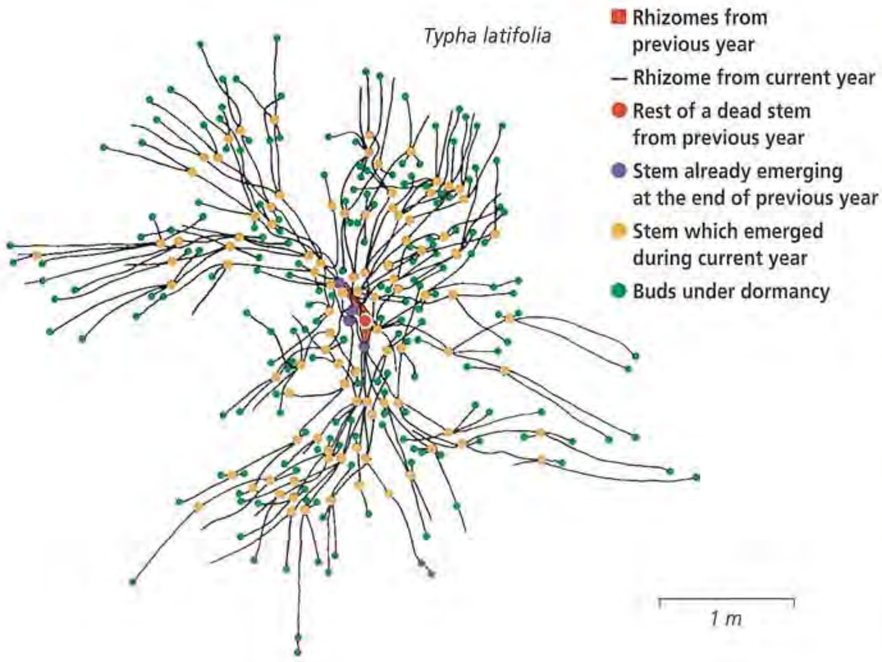
Reproduction of emergent plants

Aquatic emergent plants use two methods of reproduction: vegetative, which allows extensive colonisation over a short distance from new seedlings; and sexual, for colonisation at a short or long distance.

Vegetative reproduction

This occurs through using stolons, rhizomes or cuttings, which allow the plant to reach nearby sites more rapidly and to increase its density locally. Sexual reproduction is more chancy because of the sensitivity of young plants to slight changes in the habitat. Reedmaces and common reed produce new individuals from underground rhizomes (see figure below): a mature reedbed is capable of producing 120 shoots/m^2. The development of shoots creeping along the soil also helps the extension of the reedbed: under certain conditions (drought, an individual on the edge of the reedbed, etc.) the common reed can produce stolons of 10-15 m long in a year.

Colonisation by vegetative reproduction over a long distance is possible for species – e.g. water couch, water primrose – which can develop from small fragments ("cuttings") transported by rivers, canals, or even by animals.



Vegetative multiplication form a reedmace shoot

After Dykyjova & Kvet, 1978

The adaptation of emergent species

Sexual reproduction

Sexual reproduction is essential to maintain the genetic diversity of a population. It enables a population, as a seed bank, to resist changes which can destroy the vegetation. As seeds the emergent plants can reach new sites some distance away which could not be reached by stolons or creeping stems. These sites can be "springboards" from which massive vegetative colonisation can subsequently take place.

Cockspur *Echinochloa crus-galli* can produce 20,000 seeds/m^2, 90% of which germinate the following year.

Reedmaces produce many seeds which are carried away by the wind. To germinate they need special conditions: a good sunny position, but not excessive sun; a low level of oxygen but not anoxia; and high temperature, the optimum being 35°C. These conditions can be found in a shallow pool in summer. After germination, the young seedlings need strong sunlight, so reedmace can develop only in open spaces where there is little or no competition from other species. These conditions occur simultaneously only in disturbed areas: newly worked soil, variable water management, overgrazing.

In the common reed the seeds remain viable for at least a year. For germination there needs to be shallow water, light, temperature between 10°-30°C and adequate aeration of the soil. These conditions are found in bare areas of mud on the edge of a wetland. Tamarisk *Tamarix gallica* seeds have only a short life span; they are tolerant of relatively high levels of salinity, but require humidity to germinate. These conditions occur in summer, either after rains when the soil remains humid, or on the edge of lakes or lagoons when the water level drops.

The seed bank

The seed bank is the stock of seeds present in the soil, and includes all species; it represents the range of species that could develop locally. It is not, however, a reflection of the vegetation of the site. The proportions of seeds of the different species in the seed bank are not the same as the plant populations present.

For example, the reeds, reedmaces and club-rushes growing in a site create unfavourable conditions for the development of sea and sharp rushes. Unable to germinate, the seeds of rushes are over-represented in the soil, compared with the vegetation communities. Thus, in terms of the conservation value of the site, it is difficult to evaluate the importance of the site as a feeding site for granivorous animals (ducks, etc.) by simply referring to the dominant vegetation; the seed bank must also be surveyed.

Water and air are the principal vectors of seeds in wetlands.

Lake Fetzara, in northern Algeria, was drained in 1937 for agriculture, and remained totally dry until at least 1978. Following heavy flooding at the beginning of the 1980s, and the closure of a sluice gate at the outlet of the old lake in order to retain the water, the lake reformed and by spring 1984 hundreds of hectares where covered again with sea club-rush, bulrush and spike-rush. Without precise studies, it is not possible to say what role the seed bank could have played in this "renaissance", more than 40 years after the drainage[1].

Domestic and wild animals, particularly birds, also disperse large numbers of seeds. Through agricultural activities, man influences the seed bank by introducing new species, such as the water couch.

The qualitative and quantitative composition of the seed bank in a wetland varies with time, the conditions in the habitat and the life cycle of the species (see figure below). The seed bank, through the seeds' longevity, acts as a buffer to the inter-annual variations in the climate, and is long influenced by past activities, particularly agricultural.

As the salinity increases, the seed bank is less abundant and less diverse; and annual species dominate, a common phenomenon to ecosystems with difficult conditions.

In certain species, viable seeds are frequently found up to more than one metre deep in the sediment. The longevity of the seeds is linked to morphological factors, for example a resistant seed coat. Other mechanisms, however, not yet well-understood play a role; a small quantity of oxygen in the soils apparently limits the deterioration of the seeds, for example.

Evolution of the seed bank from one year to the next.

1 - After Chalabi et al., 1985

The adaptation of emergent species

Klein/Hubert / Bios

Reedmace produces an enormous number of tiny seeds equipped with feathery plumes to facilitate dissemination by the wind.

Numerous disturbances (human interventions or natural accidents) can modify the seed bank, and therefore the dynamics of the vegetation: fire, drought, burial of the seeds deep down by sedimentation or trampling by animals, drainage or dredging can damage the seed bank. Grazing and cutting can inhibit restoration of the seed bank and its maintenance in the long term, because the plants are cut or grazed before producing seeds.

Competition

For a plant, the ecological optimum found in nature is often different from the physiological optimum, which can be found in a single species experiment. In nature a plant often occupies a niche which is more limited than its known tolerance to habitat factors (salt, flooding, etc.) should theoretically allow.

Competition can occur between individuals of the same species ("density effect").

A number of species have similar physiological tolerances and theoretically could coexist; however, the communities which are actually found are often not very diverse, sometimes even monospecific. The phenomenon of competition plays an important role in these differences between what is expected and what is found. In many cases, the plants are found not in the ideal conditions for the species, rather in sub optimal refuges sheltered from competitors.

Competition may occur for nutrients, light, space for roots, or for any other resource available in limited quantities. Because of competition, the occurrence of a species even when it is abundant in a given situation does not mean it is perfectly adapted to the conditions found there. Permanent or temporary stresses due to salinity, flooding, fire, or desiccation which limit the production of certain plants and/or modify the habitat, change the competitive relationships and allow the dominance of those species least sensitive to these factors.

Salt marsh rush versus sea club-rush

Salt marsh rush *Juncus gerardi* and sea club-rush *Scirpus maritimus* are two species of plant which occur in marshes with shallow winter and spring flooding; they often coexist. Grazing modifies the equilibrium between the two species.The salt marsh rush is early growing, and grazing from the end of spring has little effect on this plant which has by then built up its reserves and produced its seeds. The species will do well the following year. Sea club-rush grows later than salt marsh rush and will not be able, in similar conditions, to build up good reserves, or to produce much seed due to the impact of grazing. After three years of such grazing, salt marsh rush forms a carpet which is sufficiently thick to prevent other species from establishing themselves.

But if grazing disappears or becomes less intense the sea club-rush will in two years become dominant again from the few individuals or seeds which always survive among the beds of salt marsh rush[1].

6 - *After Mesléard et al., 1995 b*

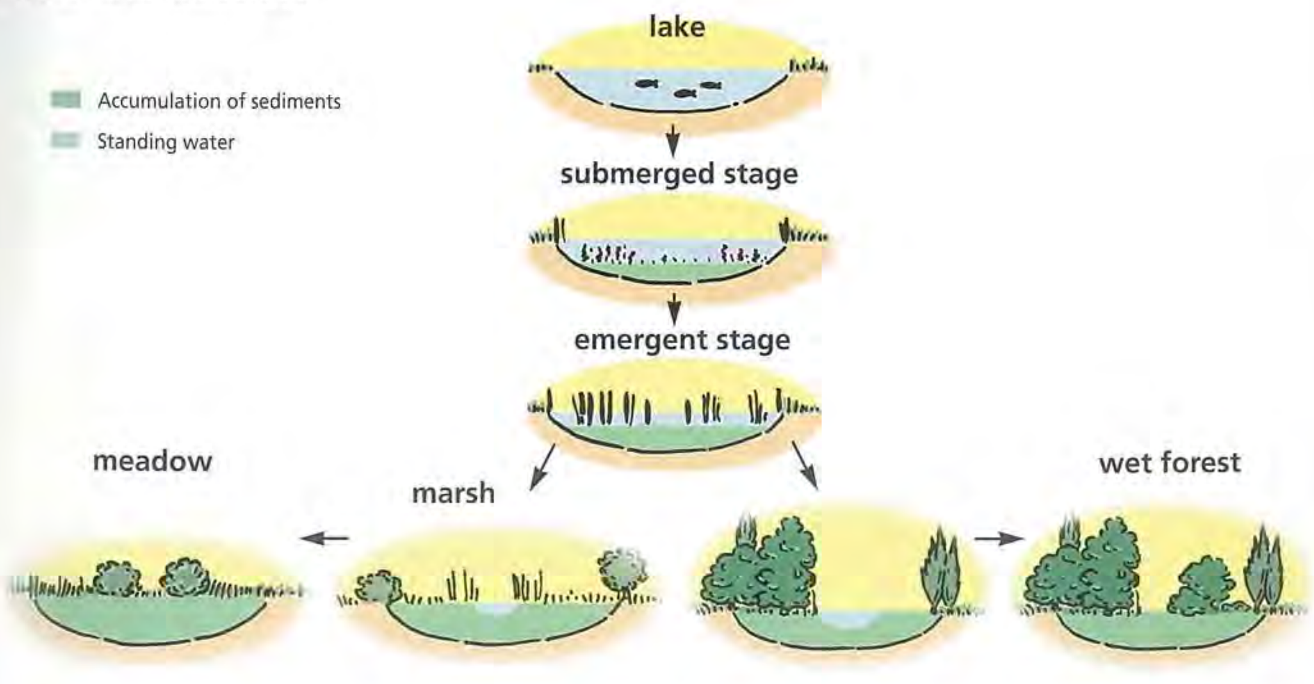
The adaptation of emergent species

The very low species diversity which characterises many Mediterranean wetlands may result from intense competition (for example, a reedbed in fresh water) or from little competition when a limiting factor excludes most species (e.g. large expanses of glassworts).

An important competitive mechanism among emergent plants is pre-emption: the species which arrives first slows or prevents the installation of another (see box on previous page). Once established, plants can use a variety of mechanisms to prevent the development of other species: by occupying all of the underground space with its roots, or by the height and density of its aerial shoots, which reduce the light reaching the soil to the extent of limiting photosynthesis by newly installed plants. These mechanisms explain why it is sometimes difficult to obtain a particular vegetation when inadequate or non-existent management has allowed invasive and more competitive plants to take over.

Competition can lead to a process whereby a series of species replaces each other: this is known as succession* (see figure below). Generally the pioneer states are of short duration and stable states are reached rapidly. The reedbed, which develops slowly towards woodland by accumulation of organic matter, can be considered as a stable state since this process occurs very slowly. The accumulation of a thick litter layer is necessary before other, more terrestrial, species appear. Various management tools can be used to maintain succession at intermediate states. Thus, grazing in a sea club-rush bed can prevent the spontaneous development of a reedbed, through selective grazing (the reeds are eaten preferentially to the sea club-rush, and a reduced accumulation of organic matter.

A lake naturally evolves towards a marshy reedbed through the accumulation of sediments and organic matter. The reedbed will itself be invaded by shrubs then trees, that will turn it into a forest.



Restoration of marshes in abandoned ricefields

In the current context of agricultural abandonment in Europe, marshes drained for agriculture and then abandoned provide an opportunity for wetland restoration. In the Marais de Vigueirat, in the eastern Camargue, France, an experiment[1] has been running since 1989 in order to measure changes in the vegetation of abandoned rice fields under different management scenarios.

The experimental area is divided into three types of water management: artificial flooding in winter (November-April), which is close to the natural conditions before the dyking of the Rhone river; summer flooding (May-October); and non-intervention (flooding by rainfall only). Each plot is divided into two halves, grazed and ungrazed.

The initial vegetation, before the experiment, was principally made up of perennial halophytes *(Arthrocnemum fruticosum, Inula crithmoides),* which had established themselves in the 15 years since agricultural abandonment. The results are summarized on page 39.

After five years the following conclusions can be drawn from this ongoing experiment:

- several years are needed for succession to stabilise; in the long term, one obtains, when water level and grazing are controlled, the installation of the tall emergents of shallow marshes: *Phragmites, Scirpus, Typha,* etc.;
- pastoral production of the areas flooded artificially (summer or winter) was multiplied by about 10 compared to the unflooded situation;
- without grazing the common reed tends to eliminate the sea club-rush under the following successional pattern

- *Juncus gerardi*

➡ *Scirpus maritimus*

➡ *Scirpus maritimus* + *Phragmites* + *Typha*

➡ *Scirpus maritimus* + *Phragmites*

➡ *Phragmites*

- summer flooding, the most difficult and costly to obtain in Mediterranean climates with their dry summers, is hard to justify for the manager. It can maintain the palatability of the sea club-rush longer into the summer (a positive aspect for grazing), but it increases the chances of invasion by reedmaces if the grazing pressure is too high, and water levels are shallow. It requires careful management, but even then there is a high risk of failure.
- the grazed areas are now important as feeding areas for duck (seeds of the sea club-rush) and to a lesser extent for waders.

1 - After Mesléard et al., 1992; Mesléard et al., 1995 ; Mesléard, 1996.

The adaptation of emergent species

The site at the beginning of the experiment.

Control site after five years.

Managed site after five years' winter flooding and grazing: salt marsh rush and sea club-rush dominate.

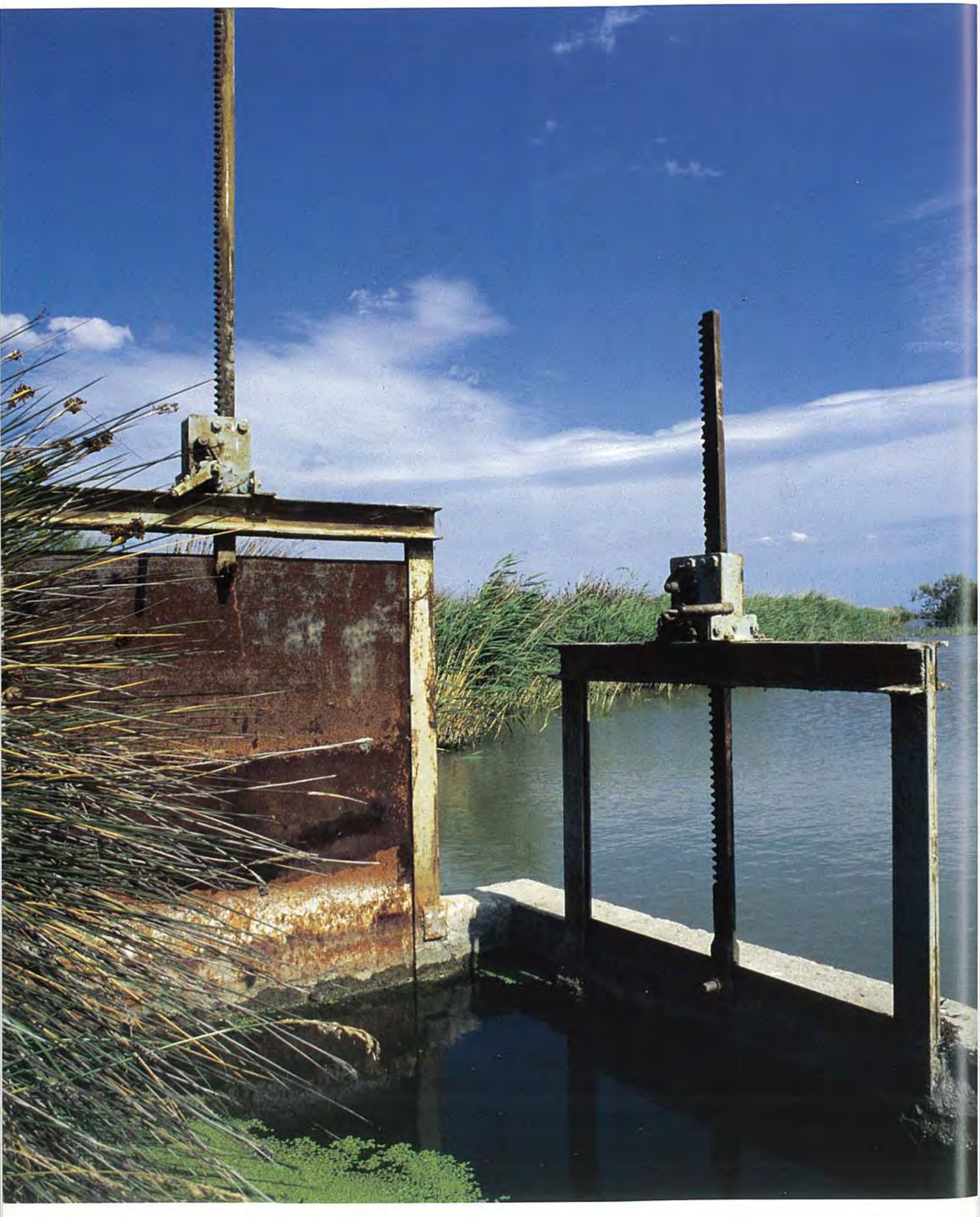
Managed site after five years' winter flooding without grazing: the reeds dominate, but the sea club-rush persists, especially in the "clearings".

Dominant vegetation and soil salinity

After 1 year	grazed	ungrazed
winter flooding	■ salt marsh rush (4.2 g/l)	■ sea club-rush + ■ salt marsh rush (4 g/l)
summer flooding	■ perennial halophytes (+ ■ sea club-rush) (7.6 g/l)	■ sea club-rush + ■ salt marsh rush (+ ■ perennial halophytes) (7 g/l)
non intervention	■ perennial halophytes (13.5 g/l)	■ perennial halophytes (14 g/l)
After 5 years	**grazed**	**ungrazed**
winter flooding	■ salt marsh rush + ■ sea club-rush (1.4 g/l)	■ reed + ■ sea club-rush + ■ salt marsh rush (1.4 g/l)
summer flooding	■ reedmace*(+ ■ sea club-rush) (1.3 g/l)	■ reed + ■ sea club-rush (1.4 g/l)
non intervention	■ perennial halophytes (13.5 g/l)	■ *Aeluropus littoralis* + ■ perennial halophytes (14 g/l)

■ perennial halophytes *(Arthrocnemum fruticosum, Inula crithmoides)*
■ sea club-rush
■ salt marsh rush
■ reedmace
■ reed
■ *Aeluropus littoralis*
( ) species not abundant

* The reedmaces were able to dominate only because of heavy grazing/trampling and unwanted random summer drying-up periods. In these conditions, if the habitat was totally freshwater, water couch *Paspalum paspalodes* would dominate.



Obtaining the desired emergent plant communities

The existing vegetation is a result not only of the current conditions (climatic, water regime, etc.), but also of past management. An understanding of all the factors, ecological, economic and social, controlling the vegetation is vital before managing the vegetation.

Why manage aquatic vegetation when one could let nature take its course? In fact, due to the long history of human impact in the Mediterranean, the processes acting on the wetlands are rarely truly natural. Active management is a rational choice of the type and intensity of artificiality, rather than a deliberate choice of "artificial rather than natural". All too often, the option of allowing nature to take its course is no longer possible, because of the impact of dams, canalisation or dyking activities.

Active water management allows flooding dates to be predetermined.

At Merja Zerga, a vast coastal lagoon of 7,000 ha in Morocco, the local community uses four plant species: *Ammophila* (grazing, roofing), reeds (grazing), the cane *Arundo donax* (fishing rods, roofing) and sea rush (floor mats, roofing, lamp fuel)[1]. At Cay in Turkey, 90% of the raw materials for a paper factory come from the reeds in Lake Eber[2].

One can manage a wetland in order to favour a particular animal or plant species, or a plant community of high conservation importance (objective: conserving biodiversity). Management can also aim to maintain traditional human activities (grazing, hunting, reed cutting), or to deal with a more recent problem, that of purifying water containing high levels of nutrients. This approach is more one of integrated management, in order to try and reach several stated objectives.

A lack of control of emergent plants generally leads to changes in the dominant species and a closing in of the habitat, which usually leads to a decline in the number of plant species and limits the interest for wildlife. This phenomenon is particularly rapid in Mediterranean wetlands, which are highly dynamic as a result of the high temperatures. Human intervention is, therefore, often necessary to reach specific objectives.

Reeds are still used to thatch roofs or to make hoop nets for fishing, as here in Turkey.

1 - After Anonymous, 1994
2 - After Skinner, pers. comm.

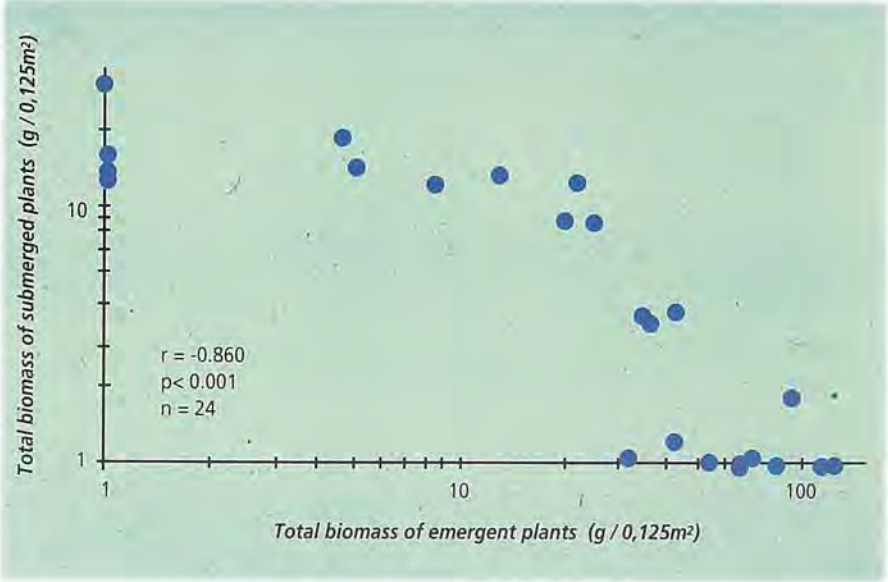
Management with conservation objectives

When one is considering the management of a natural area it is always necessary to define the short, medium and long term objectives, and list the priorities. If there are several objectives, they must be listed in order of importance; not being sufficiently clear about the priority of management objectives has often lead to failure.

The objectives and the means of achieving them must be discussed with all the people concerned; not only can this avoid criticism later on, but bring benefit from current experience and anticipation of present problems or possible future ones.

In wetlands, the emergent plants represent a varied food resource for fauna: herbivorous or granivorous waterbirds, domestic and wild herbivores. The density and size of these plants control access to food resources and directly influence the abundance of submerged plants (see figure below), which constitute a food source for other species. Emergent plants structure the habitats for the fauna by providing hiding, resting and breeding places. A wide variety of animals use these habitats: invertebrates, amphibians, fish, birds, etc.

The management objectives for emergent plants, in terms of communities, can be very varied: open habitat to provide feeding areas for ducks and herons, dense vegetation to provide nesting sites for waterbirds, wet grasslands to provide spawning ground for certain species of fish, habitats for rare plant species, etc.



In slightly brackish marshes in the Camargue, the development of submerged species is directly linked to the cover of emergent species,

After Grillas, 1992

Using aquatic plants for the treatment of sewage water

Such experiences are becoming increasingly numerous throughout the world, especially in north America and northern Europe. They are still rather few in the Mediterranean.

During the growing season, emergent plants are able to retain in their aerial parts between 250-500 kg/ha/year of nitrogen, and more than 50 kg/ha/year of phosphate. In the winter the plants release these nutrients if the plants are not harvested. However 30-88 % of the nitrate and phosphate are held in the underground parts of the plants which are not easily harvested. Floating plants (duckweed *Lemna spp.*) appear more promising, because the whole plant can be easily harvested. However, these plants do not absorb the nutrients in the sediments. Studies of this subject have all been carried in temperate climates, thus extrapolation to the Mediterranean climate is not always possible.
In summary, the requirements for using emergent macrophytes* to purify used water are[1]:

- wetlands which are created especially for this purpose, because natural wetlands may suffer degradation in the medium term;
- large areas, i.e. hundreds of hectares;
- water containing not too concentrated toxic pollutants, in order to avoid killing the plants;
- water purification needs during the plant growing period;
- monitoring and maintenance (regular harvesting) of the system.

The biological treatment of urban effluent in Egypt

In the Egyptian village of Abu Attwa, an experimental water treatment plant has been established using a reedbed on gravel[2]. The water flows through successive 90-140 m long canals, covered by experimental, commercial crops and then reeds. A reduction by a factor of 10 in the matter in suspension and oxygen requirements (an index of eutrophication) was noted. This reduction was 100-1,000 for pathogenic germs (faecal coliformes). An area of 180-280 m^2 is needed to treat 20 litre/minute in such a system.

To construct these types of wetlands in regions where land is not a limiting factor could be a solution for treatment of used water.

1 - After Vos & Opdam, 1993 and Blake & Dubois, 1982
2 - After Butler, 1992

Obtaining the desired emergent plant communities

The methods

Once the objectives have been decided, the wetland manager has a number of methods by which he can favour or limit certain plants.

Sometimes several methods are theoretically possible (cutting, grazing or fire) and the final choice will be determined by constraints and opportunities: access to water without pumping; proximity of professional reed cutters; the availability of a local hardy breed of livestock. Often the combination of several means is necessary.
As a general rule, four criteria should be considered before making the choice: the technical feasibility, the risk of deteriorating the site, the costs, and the social feasibility.

Water management

By controlling the water, the biomass and litter production is limited (by allowing drying out), and the species are selected for their tolerance to differences in flooding depth and duration. Locally, freshwater can be introduced to reduce the salinity. The further one moves away from the "natural" system by modifying the water regime, the more unstable, difficult to maintain and susceptible to invasion by undesirable species the resulting vegetation community will become. The specific details for each principal species will be developed in the last chapter (Technical fact-sheets).

The carp and the reed

In Mikri Prespa (northern Greece), the carp *Cyprinus carpio* breeds in the surrounding wet grasslands when they are flooded. These grasslands are separated from the lake by a reedbed. The spring water levels are very variable, and only in very wet years are they high enough to flood the grasslands.

But even then, carp have to find ways of getting through the reedbed to spawn in the flooded grasslands. Since the beginning of the 1980s burning of the reedbed has been forbidden and grazing by cattle has declined, so that the reedbed has become an impenetrable barrier for the fish.

In 1990 a drought opened up the reedbed. The rains of the following winter were sufficiently good to flood the grasslands, and the carp were able to find their way through the reedbed to spawn in 1991. It was a record year for carp production[1].

1 - *After A.Crivelli, pers. comm.*

Grazing

Grazing is a tool which can be used for specific management of sites, while at the same time providing an economic activity. It occurs in a majority of Mediterranean wetlands. Plant biomass can be reduced on site, and thus also the litter; grazing animals select species, and prevent the habitat from closing in; they can stop succession*. Only extensive grazing is usually compatible with conservation objectives. The main emergent species concerned are clonal ones with vegetative reproduction, e.g. reed and sea club-rush.

General information

As in other Gramineae, flowering and seed development in emergent aquatic plants is correlated to an increase in the silica content of the stems and leaves, and by a lowering in the level of nitrate. The emergent plants are therefore eaten preferentially before flowering, in the early growth period (March-May), and later only if more preferred species are not available. In contrast, the level of terpenes* in the green parts of reedmace, which are distasteful to herbivores in spring, decreases in the autumn and thus can be eaten by cattle.

General effects of grazing on plants

The impact of grazing on emergent aquatic plants is greater than on terrestrial grasses, because their density (tens per m^2) is so much lower than the latter (hundreds per m^2); a particular plant is therefore more often defoliated by grazing.

If the plant is eaten or cut below the water, emergent plant tissues can rot and result in the death of the plant. In the reed, the meristem* (the growing point) is found at the top of the stem; once eaten growth is stopped. Intensive grazing of the green parts can use up the sugar reserves in the tubers (sea club-rush) or the rhizomes* (reed) quicker than the plants can replace them by photosynthesis. In the Camargue it has been shown that grazing by horses allows emergent plants (sea club-rush, reeds) to produce only 20 % of their potential biomass[1].

Grazing often causes a decline in the production of seeds by removing the reproductive parts of the plants; it can also upset the annual cycle: flowering and seed production can be delayed by several weeks (sea club-rush), or several months (yellow flag).

1 - Duncan, 1992

This may help certain management objectives, for example a sea club-rush bed will stay palatable for longer. There will, however, be few seeds produced and few tubers, which in the long term will have an effect on the vegetation, making it less dense. As a source of food for granivorous duck, it will also be less useful.

Under the impact of grazing the preferred grazing species are controlled (reeds, sea club-rush, water couch) whilst the "avoided" species are able to develop: sharp rush *Juncus acutus*, yellow flag, reedmaces. If, however, the grazing pressure is sufficiently high even these species are grazed. Grazing also affects competition between emergent and submerged plant species. Grazing of sea club-rush by horses in the Camargue favours the development of submerged plants (*Chara spp.*, algae, water crowfoot *Ranunculus baudotti*) by giving them more light; but in return the submerged plants compete with the seedlings of sea club-rush for light. As a result the latter species declines, particularly in the deep areas of the marsh.

Finally, the input of dung and urine from the large herbivores can also affect the plants by favouring nitrogen-loving plants and accelerating the redistribution and cycling of nutrients*.

B. Pambour / Bios

Heavy grazing can reduce wetland margins to close-cropped lawns. El Rocio, Coto Doñana, Spain.

Indirect effects of grazing: trampling

Trampling by animals in wetlands, where the soil is soft and underground plant organs are exposed, damages the rhizomes and thus affects growth the following year. For other plants, such as the water couch, cutting of the stolons favours tillering (shoots that arise from the base of the stem) and vegetative reproduction. By breaking the aerial parts of the plants, trampling opens up the habitat. This is disastrous in a reedbed if there are herons breeding there, but it makes a sea club-rush bed after seed production more attractive for granivorous ducks. Heavy trampling of a habitat with shallow water in summer can open it up sufficiently to allow for the installation of reedmaces, to the detriment of the original vegetation. Trampling can also cause compaction of the soil which reduces its porosity and oxygenation. This affects the germination and growth of aquatic plants.

Comparative effect of grazing by several species

The impact of grazing by cattle, horses or sheep differs more through their effects on competition between the plants that are grazed rather than the grazing itself. By different patterns of grazing selectivity, the herbivores induce changes in the plant composition.

Cattle are the least selective, and can eat woody plants and reedmaces in the autumn, species which horses always avoid. Sheep essentially graze young and tender plants of dried-out marshes. The hardy breeds can cope better on fibrous plants, those that are bushy or high in silica, and periods of food scarcity, than the more highly bred animals can.

Aquatic vegetation is extremely productive in the summer, however during the winter months, animals must be fed with hay in the absence of grazing. Kerkini, Greece.

Obtaining the desired emergent plant communities

Hardy breeds in the Mediterranean region

Several local breeds of cattle have adapted over the centuries to grazing in wetlands in the Mediterranean: the Camargue cattle in the south of France, the dwarf cattle of Prespa (northern Greece), "vaca marismeña", cattle of the marshes in the Guadalquivir (southern Spain), the local breed of Maremma (Italy), etc. Other local breeds, not specifically adapted to wetlands, are also sometimes used for management, for example the breeds from Majorca and Minorca in S'Albufera de Majorca (Balearic islands). Hardy breeds are less fragile and lighter in weight, which is an advantage for use in wetlands.

The Asiatic water buffalo *Bubalus bubalis* was introduced to Israel a long time ago (Lake Hula), to Lake Ichkeul (Tunisia), Italy and to the lakes of Kerkini and Vistonis (Greece). Recent experimental introductions of these animals have taken place in the Balearic islands and in Aiguamolls de l'Empordà (Catalonia) to manage the vegetation. In Majorca this breed was given another name, "water cattle", in order to avoid criticism that it is an exotic species.

The fallow deer *Dama dama* has recently been introduced to Aiguamolls de l'Empordà in Catalonia in order to graze without local heavy trampling caused by more gregarious cattle.

Palatability and grazing pressures

The palatability of emergent plants varies greatly throughout the annual cycle; in spring and early summer it is comparable with that of temperate grasslands. It depends on the nutrient content (nitrogen, phosphorus and calcium) and the number of unpalatable elements: silica, terpenes in reedmaces. As an example, the following table shows some relevant values for the Camargue, France.

Contents and cattle preference for the most common emergent plants in the Camargue, France. After Mesléard, 1996

	Nitrate content (%)		Livestock preference
	Spring	*Summer*	
Reed or phragmites	3.5	2	♥♥♥♥♥
Sea club-rush	2.7	2 (dry) 3 (irrigated)	♥♥♥♥
Water couch	-		♥♥♥♥*
Salt marsh rush	2.9	1.9	♥♥♥
Aeluropus littoralis	1	1.6	♥♥
Reedmaces	-	-	♥

* lower nitrogen contents, but high productivity
- no available data

The grazing pressure is the number of animals in relation to the area grazed. If it is too low the vegetation will not be controlled; if it is too high, the vegetation can become degraded. For example, at Merja Zerga (Morocco) and at Macta marsh (Algeria) the small areas of reedbed seem to be linked to heavy grazing pressure[1]. It is therefore vital to find the right level.

The ideal grazing pressure depends on many factors: the animals, the vegetation community and its condition, annual climatic variations, seasonal variations, etc. The ideal range of grazing pressure has been calculated from a literature review and studies carried out at the Tour du Valat (see table below).

To avoid overgrazing, the use of herbivores should always include the monitoring of their impact on the habitat, using a standard methodology which will allow comparison with other areas. The alternative is to build exclosures which are at least 3 x 3 m where the vegetation is protected from the livestock. These allow the impact of the animals to be visualised and to adapt the grazing pressure between years.

Productivity (dry matter) and grazing pressures appropriate for aquatic plants[2]

Vegetation communities	Monthly production (kg of dry matter/ha/month)			Suitable grazing pressure Camargue cattle (head/*ha)**		
	Spring	Summer	Autumn	Spring	Summer	Autumn
Arthrocnemum communities	50-100	20-40	5-10	0.17-0.33	0.06-0.13	0.02-0.03
Mixed communities : halophile grassland and glassworts	300-400	150-250	50-100	1-1.3	0.5-0.8	0.17-0.33
Reedbed	250-600	100-250	?	0.8-2	0.3-0.8	?
Scirpus maritimus	400-700	30-150	0-10	1.3-2.3	0.1-2.3	0-0.03
Marsh with water couch	600-900	400-700	?	2-3	1.3-2.3	?

* Basis : 1 average Camargue cow (250 kg) eats 10 kg/day of dry matter; for horses divide the grazing pressure by 1.5.
** without damage to the vegetation community.

1 - Anonymous, 1994 and Morgan, 1982
2 - After Mesléard, pers. comm.

Obtaining the desired emergent plant communities

Fire

Fire is a widely used management tool to reduce aerial biomass and the accumulation of organic matter: dry plants and fibrous material. In North Africa fire is commonly used by local populations to burn dry reeds (e.g. Reghaïa marsh, Lake Boughzoul, Algeria[1]). Fire favours certain plants: as far as reeds are concerned burning dead litter can in fact lead to an increase in shoot density after the fire. The later fire occurs, the less it affects the accumulation of reserves and therefore the future of the plants.

Fire should always be used with great care because of the inherent risks for plants and wildlife. By reducing the aerial biomass, fire limits photosynthesis by the plants which are still green. By exposing the soil surface to high temperatures, the passage of fire can also affect rhizomes, roots and seeds. Its effect depends very much on the timing of the fire and water levels, and the strength of the wind is of prime importance. A wind which is too strong makes control very difficult and brings the risk of damage beyond the sector in question.

The impact of fire therefore depends on the period when it is used and the management used thereafter. Cheaper than cutting, fire should ideally be used at the end of winter when water levels are still high, protecting the underground parts of the plants and avoiding burning the litter. For the greatest effectiveness the use of fire can be associated with water management and the use of herbicides.

Klein/Hubert / Bios

Controlled burning allows the rapid elimination, at less cost, of large quantities of organic matter.

1 - After Jacob & Jacob, 1980 and Jacob et al., 1979

Small plots of land measuring a few square metres are fenced to keep out cattle. They are a useful indication of what the local vegetation would be in the absence of grazing.

The seablite *Salsola soda* was used in the past to produce chemical soda (sodium carbonate) by combustion. Today this plant is harvested in small amounts only, now that soda is extracted from salt. Club-rushes and great fen sedge used to be harvested to produce litter for livestock. This has practically disappeared in the north of the Mediterranean. In Merja Zerga (Morocco) harvesting the sea club-rush to make mats has declined since 1980 when equivalent mats in plastic became available at prices 3 or 4 times less[1].

Cutting the plants

Like grazing, cutting is another tool for vegetation management which can also be an economic activity. Currently only reed harvesting is widespread; the use of other species of plants has declined.

The impact of cutting

When perennial plants are cut in spring or early summer, this reduces build up of reserves and therefore the development of the plants the following year: the weight of reed rhizomes, and the amount of reserves they contain, is directly related to the size of the shoots of the previous year. Spring cutting is therefore justified only if the aim is to reduce the vegetation; as with other management tools (grazing, fire, etc.) the cutting season must, therefore, be chosen with care. In rhizomatous species (reeds, reedmaces, etc.) cutting followed by flooding or cutting under water often has very negative consequences for the plants: the availability of oxygen is blocked and the underground reserves ferment in anaerobic conditions. Reeds are particularly sensitive, while reedmaces are more resistant.

Cutting can be used as a substitute for grazing when the use of domestic herbivores is difficult or impossible. Cutting allows effective control of the large emergent plants (reedmaces, reeds, tall club-rushes, rushes) and bushy species. In addition the cutting of reedbeds reduces the build-up of litter and its consequences, sedimentation and colonisation by other species, in particular woody ones.

1 - After Anonymous, 1994

Obtaining the desired emergent plant communities

Reedbeds host species of plants and animals of high conservation value (see fact-sheets in last section) whose presence is often linked to the health and/or particular stage of the reedbed. A reedbed which is cut regularly and completely produces a habitat which is very dense and homogeneous, unfavourable for other plant species and most animals.

For example, many waterbirds need dry shoots from previous years for nest building (e.g. purple heron *Ardea purpurea*, bittern *Botaurus stellaris*, marsh harrier *Circus aeruginosus*, crake species *Porzana spp.*, bearded tit *Panurus biarmicus*, Savi's warbler *Locustella luscinioides*). A partial cut can generate an ecological heterogeneity which favours the diversity of the species and allows them to carry out complementary activities: in addition to a dense reedbed for nesting, purple herons need more open areas for fishing.

Reed harvesting in France

The production of reeds in France is estimated at 3 million bales (data from 1987), or 9,000 tonnes, of which 65-85 % are produced in the Mediterranean region, virtually all from the Petite Camargue and the edges of the Languedoc Roussillon lagoons. The market is considered as stable, two-thirds being used in France for thatching, 3-10 % exported for the same use, principally to northern Europe, and the rest used in France for matting, windbreaks, and "paille de marais" (marsh straw) when the production of ordinary straw is low.

The use of reeds is, nonetheless, negligible compared to what it used to be before modern transport allowed roof tiles to be transported throughout the country.

1 - After Schricke & EPA, 1987

Mechanical and manual uses of the reedbed

Reeds can be cut using machines, however, because the marsh soils are so soft, a machine can damage or destroy the rhizomes. Therefore machines that are specially designed for the job are necessary. By rotating the areas of reed to harvest from one year to the next the rhizomes have a chance to recuperate.

Harvesting by hand is now little practised in the north of the Mediterranean. Much less destructive than cutting by machines, it is used to maintain small reedbeds, but also locally very big ones, e.g. the Scamandre reed bed (over 3,000 ha) in the Camargue Gardoise, France. Due to the small areas cut, and the competition from machines, the income gained, like the investment, is small.

Mechanical harvesting, which requires costly investment, also presents difficulties: extensive reedbeds are declining in number because of the general degradation of Mediterranean wetlands and different management objectives; this harvest is now only a marginal economic activity.

Depending on the region, reed cutting is still largely manual...


J. Roché / Bios

...or highly mechanised.

Heavy interventions

Regularly used in northern Europe, heavy mechanical interventions (excavation, decapping, levelling) are little used in the Mediterranean region. They considerably modify the habitat, allow litter removal, removal of undesirable species, modify the hydrological context, etc. The results are often irreversible; they can be excellent or catastrophic, depending on whether the objectives have been well-thought out and properly applied. The main risks are the destruction of the seed bank, which will affect the colonisation of habitats by aquatic plants, and breaking the impermeable subsoil layer, which then prevents flooding.

Plantations and transplantations

In general, it is better to let the potential of a wetland (seed bank, tubers, etc.) develop naturally. However, the sowing of seeds or the planting of rhizomes with their efficient vegetative reproduction compensates for the loss of certain native or naturalised species and increases their rate of (re)colonisation. These techniques are also useful for filling in areas which have remained bare due to bad management (e.g. badly thought-out heavy intervention). To avoid irreversible mistakes, methods of controlling the re-established plants should be known and applicable to the site.

If whole individual plants are planted, it can be useful to reproduce these in controlled conditions first; for example, parts of the rhizomes of water couch can all become separate plants. This type of transplantation works well with reedmaces and water couch, but the success is much more random with reeds. In most species, productivity is low at the beginning, so the use of several methods of transplantation or planting is more likely to ensure success.

Transplantation of a rare species is subject to national and international regulations (conventions, European Union directives) and requires a study of the causes of their disappearance and control of the techniques. It is essential to contact the relevant national institutions, such as the Conservatoire botanique de Porquerolles, southern France.

Introductions

The introduction of exotic plants is very different to transplantations. Sometimes intentional, as with ornamental plants (water primrose; water hyacinth *Eichhornia crassipes*), introductions are most often done unwittingly. This is how water couch was introduced to the Mediterranean (France, Spain, Greece) with rice seed from America.

These introductions often have a strong, or even irreversible, impact: elimination of local species unable to resist a type of competition for which they have not been selected; uncontrollable expansion outside the managed area; disturbance to the management of the habitat, etc. Introductions are thus to be avoided.

Some introduced species, now well established in the region, such as the water couch, provide a certain pastoral and/or conservation value. Their (re)establishment locally can be done in the same way as indigenous flora, but on condition that one knows how to eliminate them with ease.

The case of water primroses *Ludwigia grandiflora* and *L. peploïdes*

These two species introduced from America are today found nearly all over France. Multiplying very quickly from pieces of the plant, they can, for example, totally invade areas of open water, or block irrigation canals. Inedible for livestock, their control requires major intervention[1] and their eradication is uncertain. The problem caused by their expansion has only recently been appreciated, to the extent that their distribution in the Mediterranean is not known. There is, however, a definite risk of expansion to other Mediterranean countries..

1 - see technical fact-sheet, page 75

Obtaining the desired emergent plant communities

P. Grillas

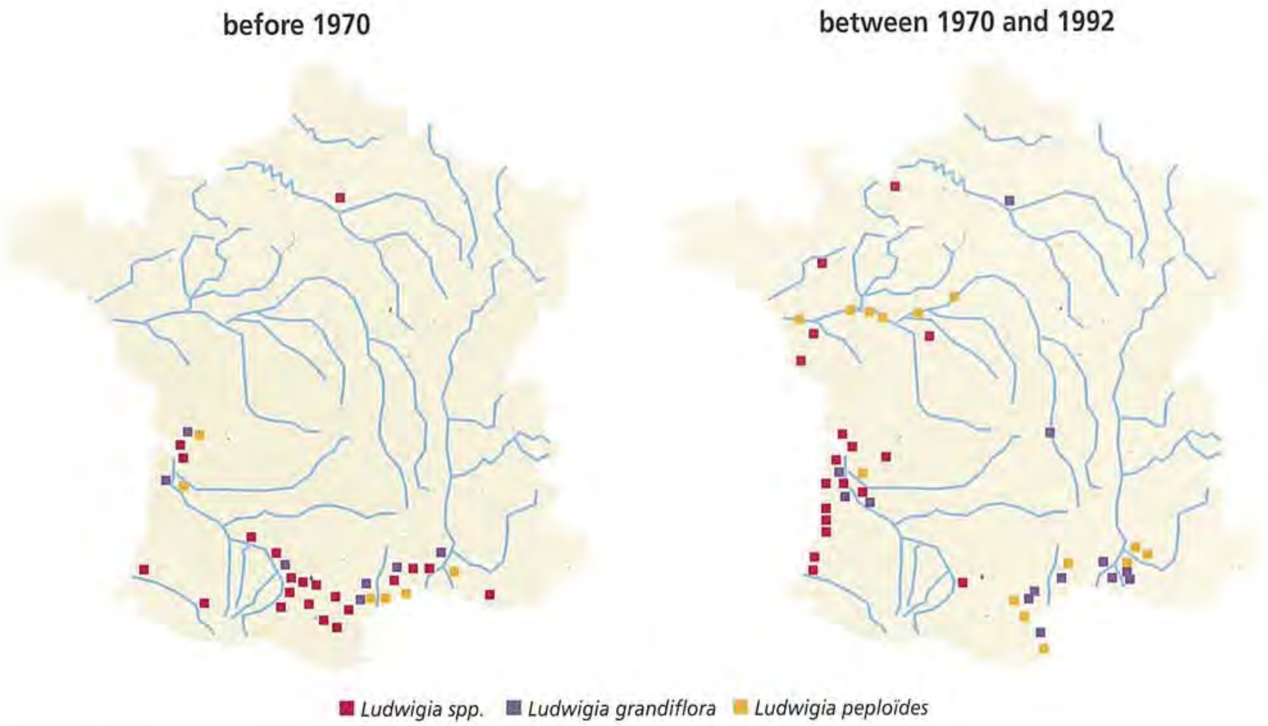
Water primroses invading a canal in the Camargue, France.

Chemical control

In principle the use of chemicals is not advised in the management of natural habitats; however, herbicides are used regularly in Anglo-Saxon countries, less so in the Mediterranean. Yellow flag is, for instance, controlled in Tour du Valat, France in such a way. Possible objectives are: the total removal of vegetation in a canal in order to help water circulation; the control of a particular species in order to favour wildlife. Herbicides can provide efficient, rapid and cheap control; they are tools which can complement other methods, to improve their efficacy. A good knowledge of the products is necessary; wrongly used they can present a risk for aquatic ecosystems.

Herbicides are the subject of considerable debate. There are other risks apart from the poisoning of non-targeted plants and the other organisms: for example, the unknown effects of the degraded plants and organisms; deoxygenation of the habitat due to bacterial degradation of decomposing plants; upsetting the ecosystem through changes in plant communities.

Most of the herbicides used in aquatic ecosystems were initially developed for use in terrestrial systems. Specific tests have since defined their toxicity



Gradual invasion of France by water primrose.

After Grillas, 1992

towards the aquatic fauna, their persistence in aquatic habitats and in flooded soils, effects on non-target plants and effectiveness on the target species. Each herbicide has specific properties, applicable under defined conditions and species.

To be effective, the quantities of the compound reaching the plant must be adequate, and must remain in contact a sufficient length of time. In aquatic habitats, because of dilution and dispersion by water, application of the herbicide by spraying on the emergent leaves is the most suitable. When this technique is not possible, the herbicide should be applied in the water to reach submerged leaves or roots. The quantities necessary should be calculated with respect to the volume of water and not the size of the area to be treated. When the current is strong the herbicide can be applied continuously to maintain a constant concentration for a given length of time.

The technique of application depends on the way each product is presented and the areas concerned. Pellets can sometimes be applied directly by hand but in most cases mechanical and motorised methods are preferable, as they allow more regular application. Liquids are sometimes directly usable but in most cases will need dilution and then application by spraying.

Obtaining the desired emergent plant communities

Inorganic compounds such as sodium arsenite are no longer used in many countries because of their impact on the environment. The most commonly accepted compounds and their targets are given in the table below. Only the active compound is mentioned, as the commercial name is often specific to a country or a firm.

In conclusion, herbicides in wetlands and in the water should not be used freely but should be limited to particular situations.

Biological control

This consists of the use of living organisms capable of limiting the development and even the eradication of plants. Biological control is generally a major operation, technically difficult and costly; and it is always difficult to foresee undesirable secondary effects and their consequences. This explains why biological control is little used in wetlands.

The introduction of new organisms causes changes in ecological equilibria, especially those maintained by competition and predation. In the absence of factors which control these newly introduced organisms, there is a risk that they will occupy a place which is too

The principal herbicides effective against emergent plants.

After ACTA, 1987.

Active element	Selective ?	For use on								Maximum efficiency	Toxicity for aquatic fauna	Remarks
		■ (Iris)	■ (Juncus)	■ (Water primrose)	■ (Reed canary-grass)	■ (Phragmites)	■ (Scirpus)	■ (Typha)	■ (Others)			
DALAPON	emergent mono-cotyledons		●●		●●	●●	●●	●	Cane	intensive photosynthesis before flowering. summer (Rhizomatous plants)	low	
DICHLOBENIL	not very	●						●		beginning of growth	Yes (use with caution)	
AMINOTRIAZOLE	not very	●	●		●●	●●	●●	●●			high concentrations	
FLURIDONE	not very							●●	Sagittaires submerged species			plants die slowly (2-4 months)
AMINOTRIAZOLE + DALAPON + THIAZAFLURON	not very				●●	●●	●	●●		summer		
GLYPHOSATE	not very	●	●●	●	●●	●●		●	Carex	flowering		

■ Iris
■ Juncus
■ Water primrose
■ Reed canary-grass
■ Phragmites
■ Scirpus
■ Typha
■ Others
● Effective ●● Very effective

important and spread beyond the target ecosystem. The use of biological agents therefore demands a knowledge of how to control them, or else the use of organisms which are unable to reproduce themselves (e.g. triploids*).

Among the experiments which have been tried in the Mediterranean is the use of the Chinese carp *Ctenopharyngodon idella*. The consumption of plants by this species increases with temperature, with an optimum between 20°-30°C; carp prefer young shoots, and their diet changes with size; they eat little at temperatures below 15°C in spite of the fact that most plants continue to grow. They are non-selective feeders but do not consume emergent plants unless there are no submerged plants to eat. Carp can therefore be a source of disturbance to ecosystems, or a management tool if the aim is to eliminate all the vegetation. In certain navigable canals in the south of France, Chinese carp are used with success to completely eliminate submerged plants. As they are unable to reproduce themselves in the north of the Mediterranean because of the low temperatures, the risk of proliferation exists only in North Africa and the Middle East. The use of triploid carp incapable of breeding is also possible.

Coypu *Myocastor coypu* and muskrat *Ondatra zibethica* control certain plants effectively, especially reedmaces which are little eaten by domestic herbivores. Nonetheless they cause serious damage (by digging into banks) and are the subject of ineffective local attempts at eradication. Their introduction, which is largely irreversible and often leads to population explosions, can therefore not be recommended.

Interactions between the different management tools and environmental factors

Each management tool, such as grazing or cutting, causes stress to plants: removal of vegetative tissues, reduction of photosynthetic potential, trampling of underground organs, etc. These stresses are often added to others of natural or human origin: pollution, eutrophication, salinity, drought, etc.

These interactions are complex and site-specific. The only general rule which should be applied in the field is caution: for example, if in a given year the drying out of a sea club-rush bed is unusually long or pronounced, grazing, even with a pressure which is normally tolerated, can be fatal; it should therefore be avoided or reduced. It is essential not to fix the management of these systems in very artificial and strict terms, as this opens the possibility of serious damage in the medium term.

Obtaining the desired emergent plant communities


D. Bringard / Bios

The Chinese carp is a voracious consumer of aquatic plants but only attacks emergent plants as a last resort.

The carp of Lake Oubeïra

In 1985/86, 6.5 million carp of five different species, including Chinese carp, were introduced to Lake Oubeïra, Algeria, for commercial fishing. By the end of the 1980s the Chinese carp had caused a decline in the reedbeds and other aquatic plants such as the rare water chestnut *Trapa natans* and white water lily *Nymphea alba.*

The lake dried out completely in 1990, resolving the problem by completely eradicating the fish. Since then carp have been reintroduced, but apparently not the Chinese species, the only one which eradicates aquatic plants: the reedbeds will therefore have the opportunity to reconstitute themselves[1].

1 - After de Belair, 1990 and A.Crivelli, pers. comm.

M. Gunther / Bios

Technical fact-sheets

The local dominance of a plant species is usually the result of precise ecological and man-made conditions.

For socio-economic or conservation reasons, replacing one type of vegetation with another can be deemed desirable; but in this case the new vegetation will be less stable as the management required (e.g. of water) will differ from natural conditions.

Newly installed species are able, through their ability to compete, to "block" all future evolution of plant communities. Their control or eradication are often long and difficult to obtain, and combining several control methods can be beneficial. A common sense rule, often forgotten, is then to avoid reproducing locally the same conditions that initially lead to the installation of the unwanted species.

The elements that permit control or development of a given species can be found in the ecological description of individual species: tolerance to flooding, salinity, grazing, etc.

The reedbed is a habitat of great biological value for specifically adapted wildlife.
Lake Mikri Prespa, Greece.

1. Common reed *(Phragmites australis)*

Reed can be either an invasive plant which needs to be eliminated, a habitat for water birds to be encouraged, or the basis of traditional, economic activities (reed cutting, grazing). A reedbed is very difficult, if not impossible, to eliminate completely; it can be damaged or weakened, but there will always be a few reeds ready to develop again into a reedbed the moment conditions are favourable.

If the management objective is water bird reproduction (ducks, herons, passerines, rails, etc.), it is recommended that management activities (cutting, burning, grazing, etc.) on the reedbed are avoided between February and mid-July nor should drying out occur during this period. All management operations should be carried out at other times.

Biological characteristics and their implications for management

- A colonial and clonal species, forming dense communities, making it difficult for other species to establish.

- Growth is mostly vegetative; up to 10-15 m horizontally in a growing season. Vast areas of reedbed sometimes result from one initial individual; the fragility of certain reedbeds may be due to their lack of genetic diversity.

- Eaten by some animals (coypu, muskrat, wild boar, geese *Anser anser*, swans *Cygnus olor* and Chinese carp) which, in large numbers, can damage a reedbed.

- With age the reedbed, because of its productivity, builds up a thick bed of litter, causing a reduction in oxygen around the roots and, in the long term, the decline of the reedbed. Rejuvenation by burning or dredging might be necessary.

Hydrological conditions required

- Tolerates water depths up to 1.50 m during the non-growing season (November-February inclusive) in France. Elsewhere it tolerates greater depths (e.g. 4-6 m in Greece), due to the large size of the plants (polyploidy*).

- Minimal depth of 5-10 cm necessary, more if possible as the reedbed would be more vigorous. The optimum is 10-30 cm.

- Improved by a drying-out period of 1-2 months (or even 3), but the soil should remain moist and the water table at about 15-20 cm below the surface; if it is lower than this the height and density of the stems may be reduced. Phragmites shows little sensitivity to the timing of the summer drying-out period (June-September); even a winter or spring dry period may benefit the reedbed.

- The lack of a drying-out period will weaken the reedbed and make it more sensitive to other disturbances (eutrophication, pollution, etc.), though not to the point of killing it. If a reedbed deteriorates in permanent water (< 1 m), there is probably another reason, but drying out can then help solve the problem.

- Sensitive to the quality of water and the sediment. Eutrophication affects it by the proliferation of filamentous algae (breaking of the stems).

Salinity conditions

- Salinity: tolerates up to 10 g/l on average during the growing season (perhaps more over very short periods), and more outside the growing season; the tolerance varies depending on the ecotype.

The ecological value of reedbeds

The reedbed community is poor in plant species, however, some of them may be of national conservation interest: great spearwort *Ranunculus lingua*, common gladiolus *Gladiolus communis*.

Reedbeds harbour a diverse fauna, invertebrates and vertebrates, and their heterogeneity provides a range of functions, e.g. for birds.

Those species that swim use the deepest parts of the reedbed: coot *Fulica atra*, great crested grebe *Podiceps cristatus* and little grebe *Tachybaptus ruficollis*, mallard *Anas platyrhynchos*, pochard *Aythya ferina*, moorhen *Gallinula chloropus*, etc. Purple heron *Ardea purpurea*, little bittern *Ixobrychus minutus* and bittern *Botaurus stellaris* nest in the shallowest parts of the reedbeds, and feed within small clearings.

Impact of grazing

- Very palatable plant for livestock (cattle and horses), very productive and nutritious (nitrogen, calcium, phosphorus). It is readily grazed when green (spring-summer), less so when it is dry (winter).

- Very sensitive to grazing by cattle and horses, because the meristem*, at the top of the shoot, is easily accessible: if it is eaten, the plant can no longer grow.

- Very sensitive to trampling (damages rhizomes), particularly in areas which are flooded almost continuously.

- Grazing is more effective in dry areas, as the animals prefer not to enter water. Grazing as a management tool is therefore less effective in deeper marshes. Water buffalo are a notable exception to this rule.

- In a particular area and in a given year, the maintenance of a reedbed and grazing are usually incompatible. However, rotation of grazing over several areas (one year grazed, 2-3 without) allows these two objectives to be achieved together.

- Examples of suitable grazing pressures: 0.8-2 cattle/ha in spring, 0.3-0.8 cattle/ha in summer.

- Outside the Mediterranean region (but not yet confirmed within it), late grazing (towards May-June) and/or a low grazing pressure (< 0.2 cattle/ha) do not have any impact on the reedbed; early grazing (from March/April) with an average grazing pressure (0.5 cattle/ha) will have a diverse impact: the dry areas will be heavily grazed, and the others will be less grazed or not at all. Finally, early grazing with a heavy pressure (> 0.5 cattle/ha) damages the reedbed.

Impact of cutting

- Cut in spring at the time of regrowth, or cut twice a year, the reedbed will not survive because it will not be able to reconstitute its reserves for the next year and will have to draw on current reserves. It is, however, not possible to eliminate reed totally the in this manner.

- Cut in winter above the water level, the reedbed will not be affected because the stems are dry and dead; but its structure (diameter of stems, etc.) can change.

- Cut (or grazed) below the water surface (or flooded after cutting/grazing), the reedbed will degrade and eventually die due to lack of oxygen and fermentation.

- Mechanical cutting (large machines) degrades the rhizomes and therefore the reedbed. It is necessary to have several years of rest between this type of harvesting.

Impact of fire

- Fire eliminates the dry stems, parasitic larvae and associated wildlife which are not very mobile. It limits the accumulation of litter. Burning in winter favours early spring growth.

- Burning of the reedbed whilst it is flooded protects rhizomes and meristems.

- Burning of the reedbed when dry, followed by flooding, can damage it (similar to the impact of cutting).

Weeding and ploughing

These operations are sometimes used in an attempt to control the reedbed, because of their destructive impact on the rhizomes. A reedbed is able to survive this impact for many years. Cutting and grazing are therefore better tools for controlling reedbeds.

Excavation

- In canals and stretches of water that must remain free of vegetation, excavation (which extracts or breaks rhizomes) slows down recolonisation by reeds.

- Little used up until now in the Mediterranean, mechanical diggers have been used in Great Britain to remove thick layers of litter which weaken reedbeds by reducing the density of stems and allow them to evolve into drier, bushy habitats[1].

For further information

Venner (1994); Burgess & Evans (1989); Trotignon (1991); Larsson (1994); Haslam (1971, 1972); Chaigne (1987); Robin (1994); Coops & Van der Velde (1995).

1 - After Venner, 1994

2. Sea club-rush (*Scirpus maritimus*)

Biological characteristics and their implications for management

- A species with strong vegetative reproduction by tubers, it also reproduces itself well by seeding.

- Seeds have a very long life (20+ years).

- Food for wildlife: seeds (duck) and tubers (greylag geese, wild boar).

Hydrological conditions required

- Very adaptable, found in habitats flooded for 2-11 months a year. It can, therefore, survive a long dry period (4-6 months) without any problems, as long as the soil, below the first few centimetres, remains moist (temporary marshes).

- Grows on the edge of shallow marshes: depth of 10-40 cm towards the end of spring (May), the optimum depth being 20 cm. It is gradually eliminated in deeper water by competition from the taller club-rushes *(S. littoralis* and *S. lacustris)* and reeds, and in the drier zones by other species such as *Aeluropus littoralis.*

- Maintaining water during the growing period (March-May) is beneficial for it, however if the water remains longer sea club-rush is likely to be replaced by the tall emergent species, reedmaces and reeds. In the short term, however, summer flooding until September improves the pastoral value of the plant, which otherwise declines from April to October.

- Requires a dry period at some point in the year, in spring, summer or late winter, otherwise deoxygenation of the substrate together with competition from taller species can cause it to decline, or disappear altogether.

- The longer the dry period (3, 4, 5 months), the more the species is under stress: low density of plants, short size, etc. This makes them more sensitive to grazing, which can eliminate them locally because they are unable to build up reserves.

- Shallow water makes sea club-rush beds (and their tubers) accessible to geese and wild boar from the autumn through to spring; large gaps may appear in the vegetation as a result.

Salinity conditions

Tolerates up to 20 g/l, but the optimum is between 4 and 10 g/l. Above this its growth is reduced, and salt marsh rush or glassworts may replace it. Low salinity levels allow growth in theory, but more competitive species such as reedmaces may then oust sea club-rush.

Impact of grazing

- Good pastoral value (for cattle and horses) in spring (from March onwards in the north of the Mediterranean) to the beginning of summer; it is lower later on (flowering from June/July). It is the most palatable aquatic plant for livestock after reeds. Grazing delays the flowering period, rejuvenating the sea club-rush bed and thus maintaining its pastoral value further into the summer.

- Examples of suitable grazing pressure: 1.3-2.3 cattle/ha in spring, 0.1-0.5 in summer, 0-0.03 in autumn.

- Trampling after seed production has the same effect as cutting (see below).

Impact of cutting

- After seed production, cutting of the aerial parts, dead and dry, has no impact on the survival of sea club-rush because the tubers are not affected. If followed by flooding, cutting opens up the habitat (as the stems are cut) and disperses the seeds into the soil; this creates a good feeding habitat for granivorous ducks.

Competition in brief

This species is easily outcompeted by common reed in the absence of grazing; under grazing it resists well; and resists competition from both reed and reedmace when there are long dry periods (several months), high salinity (> 10 g/l), or shallow water (< 20 cm).

For further information

Podlejski (1981 and 1982); Dykyjová (1986); Dykyjová & Husák (1973); Goldsmith & Stevenson (1984); Goldsmith *et al.* (1986); Clevering (1995); Mesléard *et al.* (1995 a and b).

3. "Tall" club-rushes *(Scirpus littoralis, S. lacustris)*

Biological characteristics and ecological conditions

- Taller than sea club-rush (1-2 m).

- Reproduction both vegetative and by seed.

- New shoots of *Scirpus littoralis* are readily eaten by greylag geese, in the absence of the tubers of sea club-rush (preferred).

- Little studied in the Mediterranean, most of the data on these species come from Central Europe.

Hydrological conditions required

- They grow in greater depths than the reed (max. 5 m for *Scirpus lacustris*). This species has difficulty in establishing itself in water that is not calm (the stems are not as rigid as those of reed).

- Optimal depth for a *Scirpus lacustris* in experimental conditions is 40 cm.

Salinity conditions

- *Scirpus lacustris* tolerates at least 20 g/l (it is more tolerant than sea club-rush), but prefers zero salinity.

Impact of grazing

- *Scirpus lacustris* is less palatable than sea club-rush.

For further information

Ellenberg (1988); Goldsmith & Stevenson (1984); Clevering (1995); Coops & Van der Velde (1995).

4. Great and lesser reedmaces *(Typha latifolia, T. angustifolia)*

Biological characteristics and their implications for management

- Typical pioneer plants of wetlands with disturbed soil, or with unpredictable irrigation with important variations between years.

- Produces large quantities of seed, which are dispersed by the wind. Germination, however, is very chancy because of the very specific conditions required: high temperatures (25°C or more), abundant water and light (in the red wavelengths). These conditions can be found in an open habitat (bare mud) with shallow water in summer. One should avoid creating these conditions if colonisation by reedmaces is not desired, particularly if there is a community nearby.

- Once established, it is difficult to get rid of these species because of their vigorous vegetative reproduction and their great resistance to stress.

- Not very palatable for domestic herbivores, particularly during growth (terpenes in the green parts). Coypu and muskrats eat the base of the stem and leaves which do not contain chlorophyll.

Hydrological conditions required

- Water with little or no current.

- Ideal depth is less than 40 cm (Mediterranean marshes), but it can survive up to 2-3 m in lakes and reservoirs.

  Note: other smaller species can survive in shallower areas (e.g. *Typha laxmanii* which is present in the Mediterranean, but rare).

- Do not tolerate long (more than 6 weeks) and repeated (over several years) dry periods during the growing season (March-August): this weakens the plants and in the end kills them. This is only true if the soil dries out deep down.

- In contrast, the reedmaces tolerate an absence of the drying-out period better than most of the other emergent species.

Salinity conditions

- Tolerates only low levels of salinity (max. 1.5 g/l). There are some interspecific differences: e.g. *Typha angustifolia* seems to be more tolerant of salt.

Impact of grazing

- Grazed by cattle, but not by Camargue horses, reedmaces are eaten only in autumn when there are few other plants to eat and when the grazing pressure is heavy (e.g. 2 cattle/ha). It is not certain, however, that grazing will eliminate these species, so a long drying-out period afterwards, in spring-summer, is recommended.

Impact of cutting

- Cutting has little impact if the rhizomes are not touched, because regrowth can then occur. On the other hand, anything that affects the rhizomes (metal cage-wheeled tractors) can limit the extension of the reedmaces.

For further information

Dykyjova et Kvet (1978); Coops & Van der Velde (1995).

An unexpected management tool for great and lesser reedmaces

In 1992, in the Parc Naturel de l'Aiguamolls de l'Empordà (Catalonia), the Vilaüt lagoon was completely invaded by reedmaces. This was particularly opposite the hide where the managers wanted open water to attract waterbirds for the visiting public. In 1989-1991 purple gallinule *Porphyrio porphyrio* was introduced into the park with great success. This bird loves the tender parts of great and lesser reedmaces (base of the stems); numbers increased spectacularly, and in 1993 there were about 40 birds on the lagoon busily eating reedmaces. By 1995, reedmaces had disappeared from Vilaüt, except for some small isolated clumps; the purple gallinule then started eating other species: water couch, sea club-rushes.

This example should not justify impetuous introductions, particularly of species not previously found in the habitat. Given its varied diet, the purple gallinule can cause problems locally, for example by destroying rice around wetlands[1].

1 - *After Jordi Sargatal, pers. comm.*

5. Water couch (*Paspalum paspalodes, P. distichum*)

Biological characteristics and their implications for management

- A grass species introduced from Central America to the Mediterranean with rice seed.

- A tropical plant, needing high temperatures to develop. It starts growing late in the season, about the middle of May, and then grows very rapidly.

- Vigorous vegetative reproduction; easily transplanted by installing cuttings into new sites with the right ecological conditions. Once established, sexual reproduction replaces vegetative multiplication (large numbers of seeds are produced).

- If grazed, it provides important feeding areas for duck, particularly teal *Anas crecca* and mallard *Anas platyrhynchos*.

Hydrological conditions necessary

- In favourable areas (high temperature, low salinity, etc.), it is capable of withstanding a rise in the water level, and can reach up to 1 m in height. Optimal productivity, however, occurs in shallower depths with shorter plants (10-30 cm).

- Early flooding, before mid-April, favours the large species such as reedmaces, reeds and yellow flags, which shade it and outcompete it; late (May) flooding favours it.

- A long dry period (spring + summer) eliminates the species.

Salinity conditions

- Freshwater plant: tolerates 0-4 g/l salt; disappears with higher concentrations with a low salinity (< 2 g/l); summer flooding favours "explosive" growth if the temperatures are high (> 25°C).
  Between 2 and 4 g/l, it can survive if on its own, but in natural conditions the larger emergent plants eliminate it.

- If there is a source of brackish water nearby, it is in theory possible to eliminate it.

Impact of grazing

- Of an average pastoral value, it is nevertheless much appreciated by livestock, particularly as it is available late in the season (summer) when the other plants are dry. In ideal conditions, its productivity matches that of reeds, and is higher than that of a rich temperate grassland!

- Grazing favours it, by controlling the taller species (club-rushes, reeds, etc.). Grazing is necessary for it to remain dominant.

- Example of suitable grazing pressure: 2-3 cattle/ha in spring (from mid-May, in France), and 1.3-2.3 cattle/ha in summer.

Impact of cutting

- Use of metal cage-wheeled tractors, which cut up the plant and eliminate its competitors (reedmaces, etc.), is very beneficial for the species through the production of cuttings.

For further information

Gros, 1986; Gros & Grillas, 1990; Mesléard *et al.* 1993.

P. Grillas

Water couch is an extremely productive species. On Lake Kerkini in Greece, it provides grazing for domestic water buffalo.

6. Water primroses
(Ludwigia grandiflora, L. peplodes)

Biological characteristics and their implications for management

- Introduced plants from subtropical America which have been colonising France since the 19th century. It is a problem plant in a number of regions of the world.

- Found on the edges of water courses; floating or rooted, can be more than 60 cm high.

- Vigorous vegetative reproduction; they can rapidly cover water bodies or canals, eliminating other species and hindering water circulation.

- Eaten very little (in autumn) by wild and domestic herbivores because of elements, which are distasteful.

- They do not constitute a habitat much used by Mediterranean fauna.

Hydrological conditions required

- In brackish areas (deltas), the management of water is often to desalinise the soil, and/or to reduce the dry summer period; these effects are beneficial for water primroses.

Manual removal of water primroses at the Vigueirat marshes, Camargue, France.

A. Mante

1 - After Lucchesi, pers. comm.

- *Ludwigia grandiflora* tolerates long dry periods (which are accompanied by an increase in salinity in coastal wetlands), by surviving in a prostrate form. In the long term this weakens the plant. By repeating this long dry period in 3 consecutive summers (3 months between May and September), *L. grandiflora* can be eliminated from a water body.

Salinity conditions

- Tolerates a maximum of 10 g/l of salt, but grows better in lower salinities.

Impact of weeding

- Glyphosate eliminates the plants present, but does not stop recolonisation: its application must be followed by management which does not favour the plant, and the wetland must be cut off from all other possible new sources of water primrose (e.g. canals). The secondary effects of glyphosate on aquatic ecosystems are unknown; it is advised that it should only be used exceptionally and on small areas, not on entire wetlands. The two previous methods of removal are preferable in this situation.

For further information

Grillas *et al.* (1992).

7. Glassworts
(Arthrocnemum spp., Salicornia spp.)

Halophyte communities of coastal habitats: deltas, edges of lagoons, etc.

- Principal plants: shrubby glassworts *Arthrocnemum fruticosum, A. glaucum,* also *Salicornia europea* and *S. veneta* (an endangered endemic plant of the northern Adriatic).

- Associated species: seablites *Suaeda maritima, S. fruticosa,* sea purslane *Halimione portulacoides* (often in the middle of tufts of other species), sea lavender *Limonium spp.,* saltworts *Salsola spp.*

Hydrological conditions required

- The different species of glasswort tolerate (even require) winter flooding of several months: 7-9 months for *Salicornia spp.,* 5-8 months for *Arthrocnemum spp.*

- The depth varies according to the size of the species: it must not exceed the height of the plant (10-40 cm in general), which must not remain completely submerged.

- *A. fruticosum* (50-60 cm high, often in dense communities) is less tolerant of flooding than *A. glaucum* (20-30 cm high, often in patches), and grows on sites a few centimetres higher.

- *S. europea* needs a period without flooding in the spring to germinate, so the roots obtain a firm hold.

Salinity conditions

- These vary according to the species. In summer: up to 150 g/l in soil water for *Salicornia europea;* 100 g/l for *Arthrocnemum spp.* In this season the plant is resting physiologically. *Suaeda maritima* has optimal growth at about 10 g/l.

- *A. glaucum* germinates in salinities up to 30 g/l. *S. europea* germinates best in water of 0 or 15 g/l (according to the source of information), but can still germinate in 50 g/l, though the rate of germination is 3-5 times less. Once germinated, *Salicornia spp.* have an optimal growth rate in salinity above zero.

For further information

Waisel (1972); Dijkema (1984); Berger (1985); Crawley (1986); Crawford (1987); Ellenberg 1988.

Plant species	Maximum depth	Flooding tolerance/requirements	Dry period	Average salinity accepted	Reaction to grazing	Remarks
■ ***Phragmites australis***	1.50 m in summer ideally less than 1 m in winter (certain ecotypes up to 5 m)	Water should cover or be close to the soil surface for part of the year; ideally, the water table sould not go down below 1 m	Partial dry period in summer is beneficial	Tolerates a maximum of 10 g/l	Very sensitive (cattle + horses). Trampling damages rhizomes	Weakened if there is no dry period in conditions of eutrophication high temperature
■ ***Typha spp.***	40 cm (marsh) 2-3 m (lakes, reservoirs)	seasonal flooding: favourable for germination - permanent flooding unfavourable if water shallow; eaten by coypu and muskrats	Does not tolerate long and repeated dry periods	Low: 1-1.5 g/l (depending on the species)	Controlled by cattle (not horses)	Pioneer plant typical of wetlands where the soil or irrigation is irregular
■ ***Salicornia spp.* and *Arthrocnemum spp.***	Depending on the species (tolerance = height of the individual	Flooding not necessary but can tolerate several months of flooding in winter	Tolerant of dry periods (even 12 months for *Arthrocnemum*)	Max. 150 g/l (*Salicornia europea*). 100 g/l (*Arthrocnemum*)	Withstands light grazing	Seeds eaten by granivorous ducks
■ ***Ludwigia spp.***	More than 60 cm	Ideal = permanent water (canals, reservoirs)	Survives a long summer dry period 3 months but not for more than 3 summers	Optimum = 0 maximum = 10 g/l	Not grazed	Introduced species, often invasive
■ ***Paspalum paspalodes***	Ideal: 10 cm can tolerate 1 m	Ideal: from mid-April ; with earlier flooding it can be eliminated by competition		Optimum = 0-2 g/l maximum = 4 g/l	Requires grazing from the beginning of the growing period	Very sensitive to competition from tall emergent plants; good feeding areas for ducks
■ ***Scirpus littoralis* and *lacustris***	Optimum = 40 cm (*S. littoralis*), Max. = 1-2 m	*S. lacustris* has little tolerance for choppy waters	Tolerates seasonal drying-up	Max. = 20 g/l (*S. littoralis*)	*S. littoralis* lightly grazed *S. lacustris* not grazed	
■ ***Scirpus maritimus***	In winter, max 70 cm	Flooding is beneficial during growing season	Seasonal drying-up beneficial	Tolerates 20g/l		

Glossary

Aerenchyma: a tissue in which plants can store oxygen.

Aerobic: taking place (process) or living (organism) in the presence of oxygen.

Anaerobic: taking place (process) or living (organism) in the absence of oxygen.

Annual: plant which survives from one year to the next in the form of seeds.

Anoxia: absence of oxygen in water, sediment, etc.

Clonal (species): species which can cover large areas by vegetative reproduction from one individual. The colony thus created is a group of clones of this individual (e.g. the reeds).

Dimorphic: which exists in two forms within one species.

Ecotype: a variety (rare or abundant) within a species, adapted to ecological conditions which are different from the usual ones: there are ecotypes of reeds and reedmaces which tolerate salt better than the usual populations.

Edaphic: concerning the soil.

Germination: formation of a plant from a seed.

Halophile: capable of growing in salty soils.

Halophyte: plant tolerating the presence of salt in the soil. Halophytes show optimum growth when there is more than 5 g/l of salt in the soil.

Macrophytes: large aquatic plants; includes macro-algae.

Meristem: the growth point of the plant, from which new leaves, stems or roots appear.

Monocotyledon: plants whose seeds contain only one entity (cotyledon), as opposed to dicotyledon (2 cotyledons). All grasses are monocotyledons.

Nutrients: essential elements in the soil which a plant needs for growth: nitrate, phosphorous, potassium.

Osmotic (pressure): internal pressure of a living cell, depends on the water the cell contains.

Perennial: plant whose individuals generally survive from one year to another, by rhizomes, tubers, etc. (in contrast to annuals).

Polyploidy: genetic peculiarity of individuals with more than two (instead of two: diploid) homologous chromosomes in each cell.

Reduced (soil): which has lost its oxygen (opposite: oxidized).

Rhizome: underground stem acting as a place to stock reserves which allow the individuals to survive beyond the growth period and to reproduce vegetatively.

Sedimentation: formation of a higher level of soil in a wetland, by the accumulation of sediments and organic matter.

Stolon: creeping stem, allowing vegetative colonisation by a plant.

Stress: negative factor for the plant (submersion, drying out).

Succession: natural process of development of the vegetation from one community to another, following a change in climate, sedimentation, etc. or the reconstitution of a habitat after disturbance.

Succulent: possessing enlarged organs, capable of stocking a large quantity of water in the stems, leaves, etc. (e.g. glassworts).

Terpenes: a chemical component of some plants, that repels grazing animals.

Triploid: individual with 3 (instead of 2: diploid) homologous chromosomes in each cell.

List of species mentioned in the text

Aeluropus littoralis
Agrostis stolonifera: Creeping bent
Alnus spp.: Alder
Alopecurus geniculatus: Marsh foxtail
Arthrocnemum fruticosum, A. glaucum: Glassworts
Arundo donax: Cane
Aster tripolium: Sea aster
Azolla filiculoides: Water fern
Butomus umbellatus: Fowering rush
Carex spp.: Carex
Chaetomorpha linum: Chaetomorph algae
Cladium mariscus: Great fen sedge
Cladophora spp.: Filamentous algae
Cynodon dactylon: Bermuda grass
Cyperus papyrus: Papyrus
Echinochloa crus-galli: Cockspur
Eichhornia crassipes: Water hyacinth
Eleocharis carniolica: Spike-rush
Eleocharis palustris: Common spike-rush
Galium palustre: Marsh bedstraw
Gladiolus communis: Common gladiolis
Glyceria fluitans, G. maxima: Sweet grass
Halimione portulacoides: Sea purslane
Holcus lanatus: Yorkshire fog
Inula crithmoïdes: Golden samphire
Iris pseudacorus: Yellow flag
Isoetes durieui: Quillwort
Juncus acutus: Sharp rush
Juncus bufonius: Toad rush
Juncus gerardi: Salt marsh rush
Juncus maritimus: Sea rush
Juncus pygmaeus: Pygmy rush
Juncus subnodulosus: Blunt-flowered rush
Juncus subulatus: Fine-leaved rush
Lemna spp.: Duckweed
Limonium spp.: Sea lavender
Ludwigia grandiflora, L. peploïdes: Water primrose

Lycopus europaeus: Gipsy wort
Lythrum salicaria: Purple loosestrife
Molinia caerulea: Purple moor-grass
Nymphea alba: White water lily
Oenanthes spp.: Water dropwort
Orchis palustris: Bog orchid
Paspalum paspalodes: Water couch
Phragmites australis: Common reed
Potamogeton: Pound weed
Ranunculus baudotti, R. lingua: Water crowfoots
Ruppia: Ditch grass
Salicornia europea, S. patula, S. radicans, S. veneta: Glassworts
Salix spp.: Willow
Salsola spp.: Saltworts
Scirpus cespitosus: Deergrass
Scirpus lacustris: Common club-rush or bulrush
Scirpus littoralis
Scirpus maritimus: Sea club-rush
Sparganium spp.: Bur-reed
Spartina spp: Cord grass
Spirogyra spp.: FIlamentous algae
Suaeda fruticosa, Suaeda maritima: seablites
Tamarix africana, T. aphylla, T. canariensis, T. gallica, T. tetrandra: tamarisk
Trapa natans: Water chestnut
Triglochin: Marsh arrow-grass
Typha angustifolia: Lesser reedmace
Typha latifolia: Great reedmace
Typha laxmanii
Ulva spp.
Zostera: Eel grass

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The **Station biologique de la Tour du Valat** was established in the Camargue (France) in 1954 by Dr. Luc Hoffmann as a private research institute, primarily for field ornithological studies.

In 1993 the estate consists of 2500 ha of land belonging to the Fondation Sansouire, created under French law in 1976. The estate is one of the few in the eastern Camargue on which extensive areas of near-natural landscapes have survived the post-war expansion of arable agriculture. Funding for the research and conservation programme of the Station comes from a variety of national and international organisations, but the major part of the core funding is provided by the Fondation Tour du Valat, a foundation under Swiss law.

The scientific programme of the station has evolved over the years, and has included programmes on the management of vegetation using domestic herbivores, fish ecology, optimal foraging strategies, behavioural studies, and migration and breeding success of colonial waterbirds. Most of these studies have been undertaken in the Camargue, but the Station has increasingly worked in collaboration with other scientists in the Mediterranean region.

This programme has provided the Station with a fundamental understanding of Mediterranean wetland ecology which can be applied to wetland management problems in the region.

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