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This volume arises from a series of paper presented at the 5th conference of the European Union for Coastal Conservation, COASTLINE Õ95, held in Swansea (UK) from 3-7 July 1995 (Doody 1996). In addition to providing comprehensive coverage of key issues such as coastal zone management, shoreline management, recreation and tourism and the implications of the European UnionÕs Habitat Directive (Council Directive 92/43/EEC) for coastal conservation, the conference also included three special sessions focusing on (1) Disturbance in European salt marshes; (2) Dynamics and restoration of dry dune ecosystems, (3) Hydro-ecological research in wet dune slacks. Of the 26 papers presented during sessions, seven appeared in the two volumes of proceedings published during (Healy & Doody 1995) and after (Jones et al. 1996) the conference, while another 12 are now published in this Special Feature of the *Journal of Coastal Conservation*.

These 12 contributions represent the outcome of two major research programmes, one funded by the European Community (Disturbance of salt marshes), and one by the Dutch government (Restoration of dry dunes and wet dune slacks). In producing this Special Feature the editors have attempted to bring together a selection of original research papers which illustrate the complexity, fragility and ecological significance of soft coastal ecosystems Ð salt marshes, sand dunes and dune slacksÐ in northwestern Europe. Not all the authors apply the results of their work to management, as is normally the case with papers published in this journal. However, as analyzed in the summary below, each paper examines in detail the functioning of a selected terrestrial coastal system in order to understand the nature and impacts of factors such as eutrophication, acidification and changes in the hydrological regime, and in the activity of windblown sand.

Summary of results

Van Wijnen et al. studied the effects of grazing abandonment over time on the development of salt marsh vegetation on the Dutch Wadden island of Schiermonnikoog. Changes in the species composition were monitored using vegetation maps and permanent plots. They found that the grass species *Elymus athericus* gained dominance in most vegetation types after 30 yr. Both the number of vegetation types and species richness decreased when grazing was stopped. The shift to grass-dominated vegetation types was more rapid in older salt marshes compared to younger ones. The authors hypothesized that the high nitrogen pools stored in the accumulated clay layer of older salt marshes are responsible for this rapid succession rate.

Nitrogen accumulation due to clay deposition is further treated in another paper of *van Wijnen et al.* Accretion rates were studied in three different salt marsh systems in the Wadden Sea area: Schiermonnikoog (NL), Terschelling (NL) and Skallingen (DK). The authors found that nitrogen accumulation rates were strongly related to accretion rates, and that accretion rates were similar for the three study areas. On ungrazed salt marshes, vegetation succession, which is primarily governed by accretion rate, was found to proceed in a similar manner throughout the Wadden Sea area.

Cartaxana & Catarino report on nitrogen and carbon allocation along a height gradient of an estuarine salt marsh in Portugal. They found that only 6 - 13 % of the nitrogen and 14 - 23 % of the carbon was stored in the plants. For dominating plant species, root biomass was much higher (70 - 92 % of the total biomass) than shoot biomass. Root biomass was highest in the lower salt marsh where the sediment was more unstable and subjected to tidal action.

Leendertse et al. studied the effects of nitrogen addition on the grass species *Elymus athericus* (*Elytrigia pungens*) that has become very dominant on many salt marshes in the Dutch Wadden Sea area. This increase was thought to be related to enhanced nitrogen input in the salt marshes. A nitrogen addition experiment was carried out in the greenhouse to find out if the species responded positively to nitrogen fertilization. The ^{15}N stable isotope was used to distinguish between atmospheric N-input and anthropogenic fertilizer input. They found that the species responded positively to both nitrate and ammonium additions, but only at the treatment with the highest N-additions (24 g N/m^2). They concluded that most of the added ammonium was transformed to nitrate within 14 days and that significant losses of nitrate occurred, possibly due to denitrification. A successful use of the stable ^{15}N isotope in ecological studies of nitrogen fluxes in the salt marsh environment is hampered because the ^{15}N concentrations in soil nitrogen and the added nitrogen compounds differ little.

Veer compared nitrogen mineralization rates in dune grasslands affected by grass encroachment and in still existing open dune grasslands along the Dutch mainland coast. The N-mineralization was much higher in the grass-dominated sites compared to the open and species-rich grasslands, although the N-pools were not always higher. In the grass-dominated sites the N-mineralization largely exceeded the atmospheric input. The author concluded that grass encroachment may have been triggered by atmospheric deposition, but it is enhanced by positive feedbacks in the N-cycle. Mosaic-like patterns in grass-dominated and open vegetation can best be explained by an interaction of grazing and N-availability.

Arens reports on sediment dynamics of an accreting foredune complex on the island of Schiermonnikoog; one of the few areas in The Netherlands where sand blow is allowed in the foredunes. Transport rates and resulting volume change were studied during winter and early spring. The author presents comparisons between volumetric changes derived from Digital Terrain Models (DTM) and calculated aeolian transport based on meteorological observations and current transport equations. He concludes that only for part of the year the observed volume changes correspond to the predicted transport, using standard transport equations and meteorological measurements.

Van Boxel et al. studied the effects of reactivation of artificially stabilized blowouts on the vegetation of a Dutch inner dune area. They found that the blowouts remained active and grew slowly in size and depth during the 5-yr monitoring period. The areas receiving more than 1 cm of calcareous sand was up to six times the area of the blowout. *Campylopus introflexus*, a moss species reacting positively on increased atmospheric deposition of nutrients, was sparse within the deposition area, while *Tortula ruralis*, a characteristic moss species of calcareous pioneer stages, reappeared within 3yr. Shrubs and marram grass (*Ammophila arenaria*), however, did not respond to increased sand deposition during the monitoring period.

Jungerius & van der Meulen studied the variability of sand accretion and erosion in a blowout in the Meijendel area (NL). Changes in the surface elevation were monitored, almost weekly, during one year using erosion pins. Periods of erosion alternated with periods of accumulation in a random way at almost every pin. Apparently the balance between the effects of periods of erosion and periods of accumulation determines the formation of a blowout. Although several groups of plant species preferred different areas in the blowout area, no consistent relationship was found between sand accumulation and the vegetation cover. They concluded that the formation of blowouts and adjacent dunes is not controlled by the vegetation.

Van der Veen et al. used Geographic Information System (GIS) representation of data from a permanent plot situated in an undisturbed part of the beach plain and from repeated vegetation maps to reconstruct the course of a beach plain succession spanning 42 yr on the island of Schiermonnikoog. Vegetation succession was initiated by the construction of an artificial sand dike, but was later truncated by exposure to salt water following storm damage to the dike. The penetrating salt water caused a die-back of the existing salt marsh vegetation during a relatively dry summer. By examining the course of succession across different parts of the beach plain, the authors concluded that plant biodiversity can be enhanced by stimulating natural dynamic processes.

Sival et al. studied the influence of micro-relief and decalcification depth on the groundwater composition in a freshwater dune slack. The aim of the study was to assess the perspectives for ecological restoration in a dune slack complex where most of the characteristic basiphilous pioneer species became extinct after 1977. They found that micro-relief had a strong influence on groundwater composition, but not on the discharge of calcareous groundwater onto low lying areas. The zone of exfiltration of groundwater from a larger hydrological system was expressed in the depth of the decalcification front. Although exfiltration of groundwater still occurs in peripheral areas of the slack, infiltration conditions are now dominant. Alkaline conditions in the slack can be restored temporarily by rewetting the surroundings of the slack in combination with sod cutting.

Lammerts & Grootjans present a review on experimental studies on nutrient limitation of pioneer stages in wet dune slacks. These habitats are of special signifi-

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cance for nature conservation as they often harbour endangered Red List species. Nearly all treatments point to nitrogen limitation as a key factor in these systems, although co-limitation by nitrogen and phosphorus was demonstrated for one very young slack. Potassium deficiency is apparently of minor importance as a limiter of biomass production in this type of ecosystem. Combined additions of nitrogen and phosphorus led to dominance of grass species and a decrease in the frequency of characteristic basiphilous pioneer species.

Grootjans et al. discuss the possible role of laminated microbial mats on the speed of vegetation succession in a beach plain. These microbial mats are most abundant in young tidal salt marshes, but they also occur during the early pioneer stages of freshwater dune slacks. An experiment under greenhouse conditions showed that undisturbed microbial mats had a negative influence on the growth and survival of a late-successional grass species (*Calamagrostis epigejos*), while a pioneer species (*Samolus valerandi*) was not affected. When the mats were disturbed by breaking their surface the percentage survival of the late successional species increased considerably, and the total biomass after six months was much higher. Although the experiment did not reveal the mechanisms behind the poor growth of the grass species in the presence of well-developed microbial mats, the results support the idea that the mats may assist in retarding the development of late successional stages.

Management aspects

This Special Feature focuses on salt marshes, sand dunes and dune slacks. These systems have experienced significant changes as a result of changes in land use Ð grazing and the activity of windblown sandÐ and changes in the hydrological regime Ðdrainage and extraction of groundwaterÐ particularly along the coasts of northwestern Europe. Air pollution contributed considerably to the eutrophication and acidification of large dune areas here. It is commonly accepted by managers and politicians that the resulting changes in landscape and vegetation succession have reduced biodiversity and conservation values. In order to counteract these developments, several conservation measures have been applied to stimulate intrinsic natural processes and enhance conservation values.

The spread of aggressive, competitive grass species on salt marshes and dune areas is a widespread problem, particularly on the coasts of The Netherlands, Belgium, Germany and certain parts of France. While atmospheric deposition has been implicated as major causal factor of such change, sediment accretion, and the consequent increase in substrate nitrogen, can also be important, as in the salt marsh systems studied by *van Wijnen*. Lack of domestic grazing is also significant on salt marshes, especially in older systems with a substantial nitrogen pool. Further studies will be required to investigate the role of atmospheric deposition in such systems. Within the context of dry dune systems, atmospheric nitrogen deposition may trigger the development of coarse grassland swards, but the rate of nitrogen mineralization in the soils of such stands probably exceeds total inputs arising from atmospheric deposition (*Veer*). Habitat management can be used to reduce the intensive cycling of mineral nitrogen, for example mowing or grazing helps to prevent the building-up of litter.

In dune slacks, the impact of atmospheric N-deposition can be significant in pioneer stages. Early successional stages with many Red List species are N-limited (*Lammerts & Grootjans*) and the nitrogen pools are so low that N-mineralization is probably of the same order of magnitude as atmospheric N-deposition. The rapid successional changes observed in many young dune slacks along the northwestern European coasts (van der Maarel et al. 1985; de Raeve 1989; Lammerts et al. 1995) is probably partly due to increased atmospheric N-deposition. Another major environmental factor which affects dune slack ecosystems concerns the progressive acidification of soils over time. Inflowing calcareous groundwater counteracts this trend and retards the accumulation of organic matter and associated nutrient pools. Groundwater discharge also stimulates the formation of microbial mats in the early successional stages of freshwater dune slacks. Well-developed microbial mats appear to have a distinct negative effect on the growth of late-successional species (*Grootjans et al.*). Restoration measures aimed at restoring early-successional stages with many Red List species are, therefore, much more effective in areas with a sufficient discharge of groundwater (*Sival et al.*).

The reinitiation of sand blow is a very effective conservation measure for overstabilized coastal dunes. Although the processes of sand accretion and erosion in a blowout are unpredictable (*Arens*; *Jungerius & van der Meulen*), an active blowout releases a large volume of calcareous, unleached sand for subsequent redistribution. Sand deposition not only stimulates the development of pioneer dune vegetation (*van Boxel et al.*), but also helps to combat grass encroachment in dry dune areas.

Large-scale disturbance can also be beneficial for nature conservation within the context of beach plain environments. For example, *van der Veen et al.* showed that the combination of salt water inundation and a relatively dry summer caused heavy dieback of vegetation in an area where vegetation succession was initiated following the construction of a protective sand dike. Even after 35 yr of vegetation development, succession was still being reiterated across different parts of the beach plain and resulted in the creation of a rich mosaic of habitats.

The papers in this Special Feature demonstrate that the beneficial effects of natural processes, such as sand blow and water erosion, for nature conservation in dynamical ecosystems are considerable. Such factors have not always been appreciated, indeed past management practices tended to equate conservation with protection from physical disturbance. The long-term cost of this ÔpreservationÕ is best exemplified by those systems where dynamic processes no longer operate. In such cases costly and long-term management, such as hydrological restoration and mowing, must be used to maintain biodiversity. By encouraging to base conservation management on sound scientific principles, it is hoped that this series of papers will have some impact on to biodiversity conservation along the coastline of Europe.

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