Chapter 9
Summary

Coastal salt marshes are valued as important habitats for their characteristic plant and animal life. This thesis embraces different, but related, aspects of salt-marsh development as affected by management for nature conservation. These aspects include sediment accretion, vegetation development and succession as affected by marsh drainage and livestock grazing, the impact of natural herbivores on vegetation, and the role that salt marshes may play as a habitat for herbivorous waterfowl and breeding birds. The study focuses on salt marshes on the mainland coast of the Wadden Sea. The great majority of these salt marshes developed as a result of human activities, and are, therefore, in this sense man-made or artificial.

At present, the mainland salt marshes of the Wadden Sea extend over approximately 20,000 ha. Although these marshes make up a significant part (>10%) of the total area of salt marshes that is left along the European Atlantic and Baltic coasts, they are only a shadow of the former extensive, more dynamic and diverse coastal-marsh system that graded from the sea to the low-lying Pleistocene hinterland. The man-made salt marshes developed from accretion works that were constructed in order to stimulate vertical accretion and horizontal extension of the salt marshes. The salt marshes were traditionally managed for coastal protection, livestock grazing and for the acquisition of new agricultural land as a result of the embankment of marshes. To develop salt marshes for land claim is no longer economically profitable, however. This has, over the last thirty years, facilitated a shift in management objectives from coastal protection, land claim and economic exploitation to objectives related to nature conservation. The theme of this study was to identify management procedures appropriate for meeting the new objectives in order to conserve and enhance the conservation value of the salt marshes. The main focus was on how vegetation development and succession in the artificial salt marshes depend on the dynamic interactions between vertical sediment accretion, marsh topography, drainage management and livestock grazing. As we shall see, human intervention in some of these processes (especially accretion, drainage management and livestock grazing) is essential to ensure meeting long-term conservation goals.

Study area

The main study area - where studies presented in Chapters 2 – 5 and 7 were conducted - was located in the Dollard bay, the southern part of the Ems-Dollard estuary at the border of the Netherlands and Germany. The historic development of the Dollard bay illustrates the indelible relation between Man and the present coastal landscape of the Wadden Sea, and explains the lack of natural reference sites. The Dollard bay began to develop during the 13th century, and was enlarged stepwise by storm surges into the 16th century. As in

other medieval intrusion areas, this marine ingression was, indirectly, caused by Man's impact on the coastal environment. Peat mining and drainage for agricultural purposes caused subsidence of the land which subsequently became more vulnerable to flooding. By the 16th century, further intrusion of the sea was halted by improved seawall management. Since then, land has been regained from the sea by successive reclamations of newly accreted salt marshes. Human intervention to enhance lateral expansion and vertical accretion of salt marshes began at least as early as 1740. The last reclamation in the Dollard was realized in 1924. Since then, the present salt marshes in the Dutch part of the Dollard (740 ha) developed, again as a result of accretion-enhancement measures. However, after the discontinuation of these works by the mid-1950s, the marshes have been subject to erosion (Chapter 1).

Because the Dollard salt marshes are located on a estuarine salinity gradient, the marshes are brackish, which results in differences in plant-species composition in comparison with the majority of other mainland salt marshes of the Wadden Sea, especially the presence in the Dollard of *Scirpus maritimus* and *Phragmites australis*, and the absence of *Halimione portulacoides* and *Elymus pycnanthus*.

The eastern part (460 ha) of the Dutch Dollard marshes became a nature reserve in 1981, and is thus one of the earliest nature reserves in the man-made salt marshes of the Wadden Sea. Management aims in the reserve were diverse, but may be summarized as the restoration and preservation of "natural" salt marsh with a high vegetational diversity, and the preservation and enhancement of the ornithological values, *i.e.* breeding habitats for birds and feeding habitat for grazing waterfowl, and hence the mimicry of events in more natural salt marshes. In this context, and as a management experiment, livestock grazing was reduced, and the upkeep of the artificial drainage system was suspended shortly after the reserve was established.

Vertical accretion and changes in marsh topography

In the Dollard salt-marsh nature reserve, vertical accretion was studied during the first 7–8 years after the upkeep of the artificial drainage system was discontinued (Chapter 2). Vertical accretion rates generally decreased with (a) increasing marsh elevation, and (b) increasing distance from potential sediment sources, *i.e.* intertidal mudflats, main creeks, and frequently from minor creeks. Vegetation structure (density and height) was probably an important supplementary factor in the negative relationships between vertical accretion rates and distance from mudflats and creeks. Grazing influenced accretion negatively through its impact on vegetation. A model is presented that qualitatively describes the relationships among various factors and the spatial variation in vertical accretion rates.

Typical aspects of traditionally managed, man-made marshes are an evenly distributed drainage pattern, a grazed turf of low structural diversity and a flat topography. In the reserve, however, abandonment of the drainage system led to an increased variation in the marsh topography, and hence of the abiotic diversity. The number of levees along

creeks (former ditches) increased, as did elevation differences between many of the existing levees and the marsh interiors between creeks. Furthermore, poorly drained depressions developed.

Increased soil waterlogging and decreased livestock grazing in the Dollard salt marshes
Except for levees, soil aeration decreased (or soil waterlogging increased) in the Dollard nature reserve, due to the neglect of the drainage system. Cattle showed a seaward decrease in grazing across the salt marsh, and the reduction of stocking densities resulted in a landward contraction of the grazed area (Chapter 5). Direct observation of the grazing animals, stocked at 2 ha per animal in a 126-ha large grazing unit, revealed that cattle did not visit 50% (*i.e.* the seaward parts) of the unit during the year of observation (Chapter 3). For the seaward sector of the reserve, this implies that the altered management was more or less identical to a policy of benign neglect, whereas in the landward sector cattle grazing was continued.

Decreased management and plant-species distribution patterns
Effects of the decreased management in the Dollard salt-marsh reserve on the vegetation development were studied on the basis of repeated surveys for five selected tall-growing plant species in four sections of the reserve over a period of 8–9 years (Chapter 3), and for an approximately 15-year-long period, on the basis of vegetation surveys of the entire reserve and permanent-plot recordings (Chapter 5).

Chapter 3 shows that the grazing gradient caused a difference in vegetation development between the landward and seaward parts of the marsh. *Elymus repens*, which, when the reserve was established, was mainly found on levees and in well-drained landward parts, showed a marked decrease in the landward parts. Conversely, *Aster tripolium* increased landwards, and showed a shift to higher marsh elevations. From the recovery of *E. repens* in an exclosure experiment (Chapter 5), it was inferred that these changes could only be caused by the interaction between soil waterlogging in the marsh and cattle grazing.

In the seaward parts, the direct influence of the management decreased strongly (see above). *Phragmites australis* was the only species here that showed a net increase, and probably forms the climax vegetation in the brackish Dollard marshes. *Spartina anglica* and *Scirpus maritimus* decreased strongly, partly through competitive replacement by *P. australis* and partly as a result of herbivory by greylag geese (*Anser anser*).

Impact of grubbing by greylag geese on vegetation dynamics
The Dollard is a traditional haunt for migrating greylag geese. After 1975, their maximum number during fall migration increased more than tenfold in the estuary, thus allowing assessment of goose impact on the marsh vegetation. The geese grazed above ground on grasses and dicotyledons, as well as below ground on storage organs of *Spartina anglica*

and *Scirpus maritimus*. The decrease from 1983 to 1991/1992 of these plant species could only partly be explained with replacement by later-successional species, such as *Puccinellia maritima* and *Phragmites australis* (Chapters 3 and 4). Increased soil waterlogging may have facilitated the grubbing of geese on *S. anglica*. The removal of shoots as a result of goose foraging impairs, however, the ability of *S. anglica* to survive prolonged periods of soil waterlogging (Box 1). The newly developed depressions in the Dollard marshes (Chapter 2) offered seemingly suitable habitat for *S. anglica*, but the exploitation of juvenile plants by geese prevented permanent establishment and recovery of *S. anglica* in these depressions.

The decrease of *Scirpus maritimus* occurred especially in the seaward marsh fringe, where *Scirpus* was still dominant in the early 1980s. In a *S. maritimus* stand that was exposed for one season to goose grubbing, tuber biomass needed two years to recover to a level typical for an exclosed stand. Recovery time was even longer when the accessibility of tubers to geese was experimentally enhanced with an artificial gully. Small gullies and other surface irregularities along the seaward marsh edge may thus have facilitated the severe exploitation of *S. maritimus* by geese. The removal of the above-ground biomass and the grubbing by the geese enhanced marsh erosion, which reduced the opportunities for *S. maritimus* to recover.

Interaction between grazing and abiotic factors (*i.e.* waterlogging and wave-induced erosion, respectively), may explain why neither *Spartina anglica* nor *Scirpus maritimus* could recover from an exploitation threshold (Chapter 4). Both plant species are expected to be most abundant during early stages of marsh succession. In retrospect, one may conclude that the abundance of both plant species in the Dollard salt marshes was sandwiched between ongoing salt-marsh succession and exploitation by geese.

Decreased management and 15 years of vegetation change

Vegetation surveys and permanent-plot monitoring over an approximately 15-year period following the establishment of the Dollard salt-marsh reserve, showed opposite trends of vegetation succession in the reserve (Chapter 5). This affirmed results from the study on plant-species distribution patterns over a shorter period (Chapter 3). The area of secondary pioneer vegetation increased from nil to 20%, whereas, at the same time, climax vegetation of *Phragmites australis* increased in area from 10 to 15%.

In the grazed, landward, parts of the marsh, grazing and the increased soil waterlogging interacted in several ways. The interaction amplified the impact of grazing due to an increased impact of trampling, and caused increased soil salinities due to low vegetation cover in spring. These developments explain the increase of secondary pioneer vegetation, in addition to the development of the temporarily waterlogged depressions (Chapter 2) and the seaward impact of grubbing by greylag geese (Chapter 4). Exclosures that were installed half-way through the study period, showed a decline in soil salinity, and a relatively rapid recovery of plant species, such as *Elymus repens*, that dwindled during the first half of the study period.

Micropatterns in a Festuca rubra-dominated salt marsh induced by sheep grazing

Micropatterns induced by sheep grazing were studied in a grazing trial with four stocking densities (1.5, 3, 4.5 and 10 sheep/ha) and an ungrazed control treatment in a *Festuca rubra*-dominated artificial salt marsh on the mainland coast of northern Germany during three consecutive years, five to seven years after the grazing trial started (Chapter 6). The micropatterns were located in the intermediate zone of a seaward decreasing grazing gradient, comparable to the grazing gradient of livestock in the Dollard and other man-made marshes in the Wadden Sea. The micropatterns were formed by a mosaic of short and tall *F. rubra* stands on a scale of square decimetres.

Micropatterns were only found in the lightly to moderately stocked treatments (1.5–4.5 sheep/ha). In contrast with inland situations, micropatterns induced by grazing were often not stable from one year to the other, because abiotic factors, such as weather conditions and sedimentation, overruled the effects of sheep grazing in the more dynamic salt-marsh system. Micropatterns featured the highest spatial diversity in the 3 sheep/ha treatment, but since the micropatterns did not have long-term stability, a further increase in spatial diversity is not to be expected.

Habitat selection of greylag geese and barnacle geese in relation to salt-marsh management

Habitat selection and diet composition of greylag geese and barnacle geese were studied during fall and spring staging in the salt-marsh reserve in the Dollard estuary, and two adjoining salt-marsh sectors with different management in respect to drainage and livestock grazing (Chapter 7). The study was conducted after the period of considerable decline of *Scirpus maritimus* and *Spartina anglica* (Chapter 3).

Geese were highly dependent on short-grass communities, including *Elymus repens*-dominated vegetation. Barnacle geese were more selective than greylag geese. During the autumn, considerable numbers of barnacle geese could be present in the reserve, but they showed a strong preference for habitats in a salt-marsh sector outside the reserve that was intensively grazed by livestock. It was only during spring that barnacle geese also showed a preference for some short-grass communities in the reserve.

Vegetation changes in the salt-marsh reserve implied a decrease of its potential value for staging geese. Both the increased *Phragmites australis* vegetation and the increased secondary pioneer vegetation (Chapter 5) were of low value to geese. Short-grass communities in the Dollard marshes, and thus their value for staging geese, can in practice only be preserved by livestock grazing. This finding is of wide application to other mainland salt marshes of the Wadden Sea.

Constraints on nature conservation in the mainland salt marshes of the Wadden Sea

During the last thirty years, the mainland salt marshes of the Wadden Sea have arrived at a crossroads where management objectives have shifted from economic exploitation and coastal protection to nature conservation. Management objectives for nature conservation of the salt marshes have to encompass the following major constraints (Chapter 8):

- Restoration of the salt marshes to their pristine state is unrealistic.
- Knowledge of reference areas that may aid in formulating and evaluating management objectives is still incomplete.
- Preservation of most of the existing salt marshes is dependent on human activities on the seaward marsh boundary, which results in spatial fixation of the marshes and consequently leads to marsh maturation and a decline in the spatial extent of young successional stages.
- The entire range of successional stages, from pioneer to climax, can only be maintained if the management package includes livestock grazing.

Implication for management practices

Evaluation of management practices that are needed in order to preserve and enhance the conservation value of the mainland salt marshes does not yield a simple answer (Chapter 8). Species have conflicting habitat requirements, and it may be an illusion to assume that these requirements can be fulfilled under a single management regime. This conflict may be illustrated by the example of the Dollard salt-marsh reserve, where the management package combined suspension of the upkeep of the artificial drainage with a reduction in stocking rates (cattle). The reserve has become more diverse in comparison with traditionally economically exploited marshes, but the management package has not been adequate in every aspect. A uniform treatment in all marshes could thus reduce what once must have been a greater set of salt-marsh habitats than now exists.

In order to preserve young successional stages, benign neglect of the artificial drainage system may not be sufficient. Only if the management package includes livestock grazing will low salt-marsh communities persist. Alternatively, preservation of young stages may be achieved by mitigating the spatial fixation of the salt marshes by the introduction of long-term erosion-accretion cycles on the seaward boundary of the marshes.

Research perspectives

The great majority of studies on sediment-accretion rates in salt marshes have been descriptive. They have shown that accretion rates are influenced by several, often interrelated, factors, such as marsh elevation and flooding regime, distance from sediment sources and vegetation (Chapters 2, 8). The weight of separate factors can only be

assessed if factors are controlled in a more experimental research approach. Ideally, an integrated approach which includes both sedimentology and ecology is called for.

Livestock grazing facilitates grazing by herbivorous waterfowl in the mainland salt marshes. This does not preclude that grazing by waterfowl may also influence vegetation dynamics of the marshes. In response to an overall population increase, barnacle geese colonized the Dollard salt marshes during the 1970s and 1980s (Chapter 8). Peak numbers during spring increased at a rate of 40% per annum until numbers stabilized during the 1990s at a level of about 25,000 birds. This levelling off was not consistent with a continued population increase in the species, which may indicate that the geese reached an upper limit in numbers in the Dollard salt marshes. It is suggested that the geese exploit the marsh vegetation to such an extent that they enhance the transition from *Puccinellia maritima*-dominated marsh towards a secondary pioneer community as a result of the interaction between goose grazing and soil waterlogging. Because of the continued increase of goose populations and the concurrent decreasing drainage measures in Dutch mainland salt marshes, more salt marshes may become affected in future by a high level of exploitation by geese. There is an urgent need to establish goose exclosures in a number of sites, and to follow events in the coming years in combination with the detailed study of soil and vegetation. The results of these experiments can be scaled up with the aid of large-scale monitoring of both vegetation and bird populations to the whole Wadden Sea area.