17 Animal Life on Coastal Dunes: From Exploitation and Prosecution to Protection and Monitoring

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17.1 Introduction

The attitude of humans towards dune mammals and birds has changed throughout history. Initially, in the Middle Ages, wild animals and grazing stock provided food and fur. In Europe, for example, rabbits played a crucial role as meat, fur and felt (van Dam 2001a). Birds provided meat and eggs while deer were hunted for the excellent taste of their meat. Such animal exploitation lasted until the beginning of the 20th century, when bird protection incited habitat protection. The result was that animal groups other than birds were protected as well. Nowadays, dune management aims at the conservation of biodiversity and the stimulation of characteristic processes like dune rejuvenation. To integrate nature with other coastal socio-economic functions as tourism, coastal zone management (CZM) is coming into practice on a worldwide scale. Its implementation requires the knowledge and monitoring of biotic interactions between animals and their effects on the dune ecosystem. This chapter illustrates the change in attitude of humans to dune animals since the Middle Ages and the role biotic interactions have played in coastal dune conservation. Exploitation of economically profitable species and prosecution of predators were the essentials in the past; protection and preservation are the main purposes now and in the future. Do we have the adequate methods to reach this aim? We have gathered the existing information, mostly from European and North American dune reserves, in order to analyze the above.

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17.2 Cropping Stock and Game: The Medieval Coastal Dunes as a Store of Animal Goods

Sand dunes were among the earliest sites that were colonized on the Atlantic coasts of Europe and North America as well as on the Mediterranean coasts (Ranwell 1972; Doody 2001). In these environments, dune animals, both stock and game, served as an important food source: sand dunes were used as meat stores. In the Dutch dunes, for example, human settlements of 3000 and 2000 B.C. revealed remnants of sheep, goats, swine and dogs, indicating the utilization of these animals in everyday life (Klijn and Bakker 1992). Since the Middle Ages until recently, Dutch sand dunes have been grazed by herds of cattle and sheep, that were used for their meat, fur and wool (Baeyens and Duyve 1992). In the Mediterranean, sheep herding has been known for as long as 8000 years (Doody 2001). This intense habitat exploitation occurred over many centuries and throughout Europe. In fact, because of this impact of grazing on community dynamics, Doody tempers the view of those that consider many European coastal habitats as purely natural.

In Europe, grazing by domestic stock has influenced dune formation, vegetation and landscape. Grazing impedes vegetation succession; the development from grassland into scrub and woodland is slackened because trampling can cause erosion that in turn can be enhanced by the wind. In fact, Ranwell (1972) stated that "the structure of sand dune communities in Europe prior myxomatosis (before 1955) was the product of intensive rabbit-grazing". Van Dam (2001b), who recently studied the economic and ecological role of the rabbit in the medieval sand dunes of The Netherlands, goes even further by defining the outer dunes (along the seaside) as a man-made "rabbit garden". Grazing rabbits (*Oryctolagus caniculus*) keep the vegetation short and prevent trees and shrubs from sprouting. Their frequent burrowing for digging up roots as well as for making underground nests and corridors can originate blowouts, when it is done on a large scale.

In the Middle Ages, the rabbit density was artificially enlarged. From the 13th to the 18th century, sand dunes in Britain, Ireland, The Netherlands, Belgium, France and Denmark were used extensively as rabbit warrens (Klijn and Bakker 1992; van Dam 2001b; Doody 2001). Rabbits were cherished by gourmet cooks and by skin sellers. Rabbit hunting was a privilege of the nobility, who were usually the owners of the dune wilderness. Counts and lords urged the warreners to pamper their rabbits by feeding them in wintertime, expelling cats and dogs, prosecuting wild predators and even by deterring shelduck (*Tadorna tadorna*) from nesting in rabbit burrows (Baeyens and Duyve 1992; van Dam 2001a). Such measures can be considered as an initial effort of conservation and management of animals in sand dunes. Thus, the animal harvest was protected and enlarged everywhere, by reducing predation risks. In The Netherlands and probably throughout western Europe, sev-

eral terrestrial and avian predator species were prosecuted for being direct competitors of the hunting men: hen harriers (*Circus cyaneus*) (Dijksen 1992), foxes (*Vulpes vulpes*) (Klijn and Bakker 1992), stoat (*Mustela erminea*) and polecat (*Mustela putorius*) (Mulder 1990). Predator prosecution persisted until the 20th century and is locally still common practice, especially in Southern Europe, where illegal hunting is commonplace (Tucker and Evans 1997).

The improvement and creation of suitable habitats were other ways to entice palatable species. So, wintering waterfowl have been cropped since the Middle Ages in marshes and ponds in the USA and in Europe (Ranwell 1972). Habitat management of pools, by excavation and by controlling tall marsh growth, has increased the catch, in the past and still in the present. During the 16th, 17th and 18th centuries, the Dutch dunes and shores provided several bird products (Baeyens and Duyve 1992). The omelettes of gull eggs were so much in demand that in 1524 a ban was declared to stop the egg collection. Eggs of geese (Anserinae), lapwings (*Vanellus vanellus*), and plovers (Charadriidae) were also considered a delicacy. Dead gulls (Laridae) were plucked carefully and the feathers desalinated in order to stuff bed mattresses.

Introducing and breeding animal species, especially those that were of culinary value, regularly enlarged the animal crop. Partridges (*Perdix perdix*) and pheasants (*Phasianus colchicus*) were bred like poultry, set free and then shot in the following hunting season. The hunting of pheasants was often combined with corn feeding in the winter season, to lower the natural mortality. These practices were not specifically confined to the dunes but to any large part of land that was used as wilderness. Red deer (*Cervus elaphus*) and fallow deer (*Dama dama*) were intentionally introduced in the Dutch coastal dunes by Prince Maurice (1584–1625) in order to savour the delicious meat. Deer were bought elsewhere and then set free in the dunes so that they could breed and have young. Also roe deer (*Capreolus capreolus*) were hunted under his reign. However, the three species disappeared again during the 17th and 18th centuries (Klijn and Bakker 1992) and only the rabbits remained as permanent catch.

17.3 Nature Conservation Starts with Bird Protection

Hunting rabbits, birds and other animals remained an age-long practice as far as historical data reveal. In the 19th century, the shotgun was carried by quite a different type of men: the ornithologists. They shot birds to stuff them as artist's models. The most elaborate portraits were drawn with the finest detail. In Europe and the US several bird atlases were issued which in turn stimulated bird watching as a sport. Curiosity lead to admiration and admiration

lead to greediness as well as to protection. In The Netherlands and elsewhere it came into vogue to attach stuffed birds, wings or tails on lady's hats. This infuriated some bird-lovers to such an extent that the Dutch Association for Bird Protection was founded in 1899. Soon thereafter other unions and associations for nature conservation followed. The British were pioneers in nature protection legislature and the first conservation acts were created: the Sea Birds Protection Act (1869), the Wild Birds Protection Act (1872) and the Wildlfowl Protection Act (1876) (Doody 2001). In 1903, President Roosevelt signed an act to protect egrets, herons and other species on Pelican Island, off the coast of Florida. In 1936 the first Dutch law for bird protection was issued.

Gradually, species protection lead to habitat protection. This triggered the set up of the first wildlife refuges on the coast and elsewhere which later developed into the National Wildlife Refuge System in North America. In Europe and in North America, the first transcontinental studies on bird migration revealed the importance of dunes (and shores) as flyway and stepping stone along the migratory routes. Hence, the increasing need to conserve sites for migratory animals led to several international conventions such as the Western Hemisphere Shorebird Network. This was launched in 1985, covering bird flyways from both North and South America, from the Arctic to Tierra del Fuego (Doody 2001).

In the European Low Countries, the numbers of several coastal bird species increased spectacularly during the 20th century. According to Spaans (1998), the booming numbers of gulls were brought about by the cessation of the heavy prosecution. Early in the 20th century, only the black-headed gull (*Larus ridibundus*) and the herring gull (*L. argentatus*) bred in The Netherlands and both were rather scarce. Between 1908 and 1993, six additional gull species colonized the Dutch coast. The total numbers increased from a few tens of thousands to just over 250,000 in 1996.

Another spectacular numerical increment occurred in waterfowl, following a change in dune management. In the second half of the 19th century, large parts of the mainland coast of The Netherlands were utilized for drinking water extraction. This public function safeguarded the dune reserves from being built over and enhanced nature conservation. When the original aquifers did not supply enough water for the expanding urban populations, the dunes were artificially recharged with river water. Therefore large open water basins were laid out in three dune reserves between 1940 and 1965. Even before then, however, mallard (*Anas platyrhynchos*), shoveler (*Anas clypeata*) and shelduck were already breeding in the dunes. Between 1955 and 1970, other species appeared and numbers increased fast, teal (*Anas crecca*), gadwall (*Anas strepera*), tufted duck (*Aythia fuligula*) and pochard (*Aythia ferina*) (Baeyens and Vader 1990).

The colonization of the dunes by so many new bird species incited many bird watchers to regular monitoring and habitat protection. As a consequence, and step by step, the habitat as a whole gained public interest (van der Meulen

and Udo de Haes 1996). Since approximately 1920, the younger sand dunes were progressively opened to the public and an outing to the dunes became more and more fashionable. Getting acquainted with sand dunes and with nature in general aroused a gradual change in attitude.

Social and political events also played an important role in the conservation of sand dune fauna. In the beginning of the 20th century, the outer dunes in western Europe were barren and sandy because of the superabundant rabbits and also because of the desiccation due to ground water extraction. The farmers who built their farm houses in the inner dune slacks, between 1850 and 1930 (Fig. 17.1), were still hunting waterfowl, pheasants, partridges, woodcock (*Scolopax rusticola*), and rabbits. Nature associations as well as governmental institutions started to acquire the first estates, also in coastal dunes. During the Second World War, most European dunes became military grounds, forbidden for the inhabitants and general public. After that, from 1945 to 1970, the European population worked hard at the post-war reconstruction. When the standard of living increased and people had free time during the weekends, nature, including sand dunes, became more enjoyable and tourist centers were developed. From 1970 onwards, nature lovers faced with increasing apprehension the recreational pressure from leisure seekers, whose massive trampling had deleterious effects on the ecosystem. This con-

Fig. 17.1. The exploitation of dune slacks in Belgium in 1904. In between the barren and eroding dunes, the moist slacks were cultivated by fishermen, despite the relative low soil fertility. The soil was enriched with pomace. Grazing stock was confined to the salt marshes further down the coast. These fields were too vulnerable for erosion and therefore protected by hedgerows and sometimes covered with poplar twigs (Photograph by J. Massart, in Vanhecke et al. 1981)

cern resulted in the development of protective legislature in all coastal European countries so that the golden fringe of Europe was conserved (Udo de Haes and Wolters 1992)! The socio-political distinction brought about a physical segregation between leisure space and room for nature, which nowadays takes shape in coastal zone management (Van der Meulen and Udo de Haes 1996; Rigg 1999).

17.4 The Complexity of Biotic Interactions

Biotic interactions lead to additional environmental problems. In medieval times, the dunes were over-cropped by grazing stock as well as by rabbits. Rabbits regularly escaped from the warrens but could never develop a wild population due to predation and food shortage in winter. When deforestation (i.e., reduction of predators) and agriculture (i.e., more food) changed the dunes into more hospitable habitats, the rabbits spread in such large numbers that they became considered as pest (van Dam 2001a). In the 17th century, the Dutch tried to "depopulate" the dunes by hunting rabbits intensely. Domestic stock also brought both benefit (in dune slacks) and damage (on dune ridges) (Drees and Olff 2001). Since 1344, the Dutch authorities promulgated law after law to safeguard the marram grass plantations from being grazed. Herding sheep, goats and cattle in the sea barrier was strictly forbidden (Baeyens and Duyve 1992).

Pine plantations were discovered as the sovereign remedy to fix drifting sand in the Atlantic, Baltic and Mediterranean coasts of Europe (Ranwell 1972). Between 1850 and 1950 large parts (ca. 40 %) of the coastal dunes were afforested with mainly *Pinus nigra*, *Pinus sylvestris* and *Pinus maritima* (Tucker and Evans 1997). Later and even today, the planting of *Eucalyptus camaldulensis* became fashionable around the Mediterranean basin. Later, sea buckthorn (*Hippophae rhamnoides*) a native European dune stabilizer was introduced in Great Britain, Belgium and Ireland. However, its rapid expansion became a serious threat to dune slacks and open dunes which therefore was counteracted by physical removal and treatment with an appropriate herbicide (Doody 2001).

The fixation of European dunes with pine plantations also attracted animals that depend on conifers for nesting and feeding. In the second half of the 20th century, pinewoods and their inhabitants were designated as extraneous organisms in sand dunes but the complete removal of the alien conifers was not considered acceptable. In Great Britain (Houston 1995; Shuttleworth and Gurnell 2001) and in The Netherlands, they are preserved for the sake of red squirrels (*Sciurus vulgaris*), birds of prey and migrating crossbills (*Loxia curvirostra*). Furthermore, pine woods are particularly enjoyed by tourists and visitors since they offer amenity, nature and shade (Ranwell 1972).

In 1954, the fixation of sand dunes in Western Europe was boosted by a totally unexpected event: the outbreak of myxomatosis in the wild rabbit populations. In the Dutch dunes, the population drop was nearly 100 % (van Breukelen, unpublished data).

The cessation of rabbit grazing favoured the sprouting of a new generation of scrub species. According to the sequential analysis of aerial photographs of 1185 ha of the Amsterdam Water Supply Dunes, the scrub coverage increased from 17 % in 1958 to 38 % in 1979. A similar trend in scrub encroachment was measured in all dunes of The Netherlands and Flanders (Belgium) (van Til et al. 2002). Scrub encroachment was enhanced by an increase in annual precipitation in the same period. The rainwater contained more and more nitrogen (Stuyfzand 1991), so that three factors acted at the same time. In areas where the water table rose, coincidentally also from 1955–1960 onwards, landscape succession was further accelerated. In the dry parts of the dunes, scrub plant cover of ca 40 % was reached in 20 years, while in the moist parts, this was reached in ten. The rising ground water table stimulated plant growth and at the same time reduced rabbit grazing because rabbits are unable to dig burrows in wet sand.

The reduction of open and short vegetation resulted in the reduction of foraging habitat for bird species as wheatear (*Oenanthe oenanthe*) and sky-

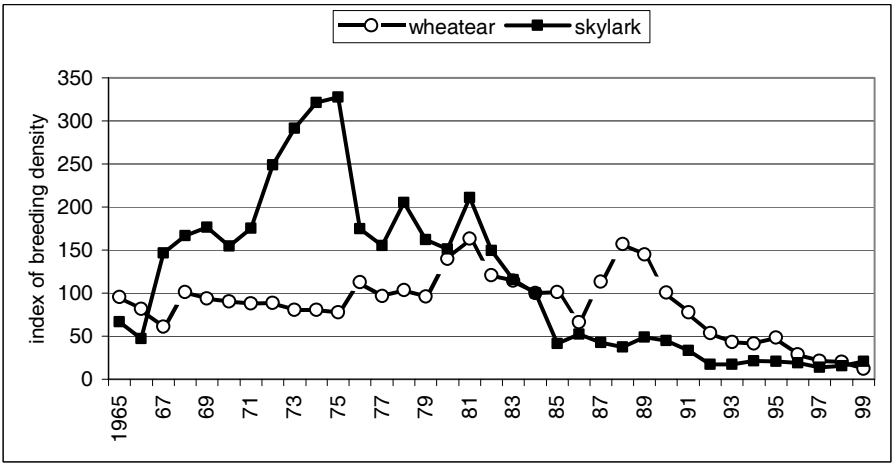

Fig. 17.2. Indexes of breeding densities of birds nesting in open dune vegetation in the mainland coast of Holland (the index of 1984 is set as 100). One would expect these breeding densities to decline to the same extent as the scrub expands and for the last 10 years this expectation meets the data. The increase in skylark (*Alauda arvensis)* numbers from the end of the 1960s is, however, in contradiction with this, and so are the fluctuations of the wheatear (*Oenanthe oenanthe)* index. The preference for nesting in open dunes and the avoidance of scrub are documented in various underlying local studies but the knowledge to interpret these trends as a whole is still lacking (Data from de Nobel et al. 2001)

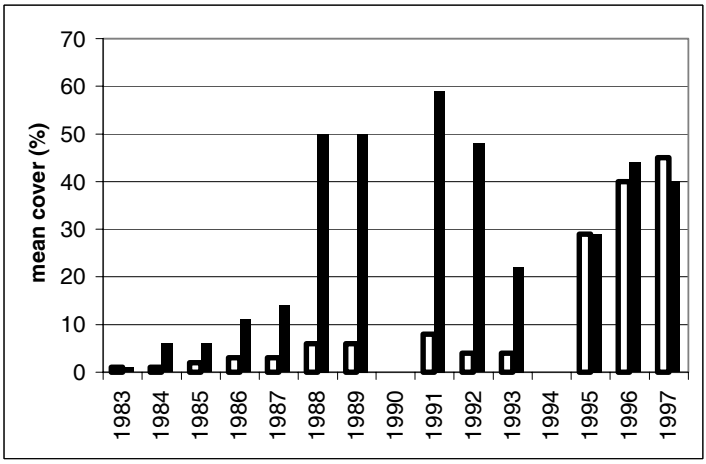

Fig. 17.3. Mean percentage of coverage by wood small reed (*Calamagrostis epigejos*) in a Dutch dune reserve, within a set of exclosures (*black bars*) and in unfenced reference areas (*open bars*). The dominance of wood small reed in the reference areas is now equal to the coverage within the exclosures since rabbit grazing has stopped in both situations. (Data from Snater 1999)

lark (*Alauda arvensis*). The wheatear showed a clear preference for short-grazed and moss vegetation, where it picked up food items more frequently: 24.3 pecks/5 min in moss and 8 or less in other vegetation types (NV PWN 2000). The breeding densities of bird species of open vegetation declined as the scrub coverage progressed (Verstrael and Van Dijk 1996; Fig. 17.2). Because of that, in countries such as Belgium, sea buckthorn is removed on purpose to optimize densities of birds breeding in open mosaic vegetation (Bonte and Hoffmann 2001). In fact, the response of birds breeding in open and short vegetation to scrub encroachment was a response to the fading away of the rabbit (Sierdsema, pers. comm.; Fig. 17.3). Before 1994, rabbit grazing restrained grass encroachment. Since 1994, rabbit populations have collapsed due to the epidemic impact of a new virus: VHD (viral haemorrhagic disease). The dominance of wood small reed in the reference areas is now equal to the coverage within the exclosures since in neither of both situations any grazing occurs (Fig. 17.3). Scrub encroachment was however favourable for bird species breeding in scrubs, like nightingale (*Luscinia megarhynchos*), whitethroat (*Sylvia communis*) and lesser whitethroat (*Sylvia curruca*); their numbers increased (Fig. 17.4).

Additionally, the reappearance of the red fox in the mainland dunes also affected meadow birds, and the breeding numbers decreased even (Van der Vliet and Baeyens 1995; van der Meer 1996; Veenstra and Geelhoed 1997). Other ground-breeding species like pheasant, partridge and woodcock also suffered from the increase of predation pressure (Koning and Baeyens 1990,

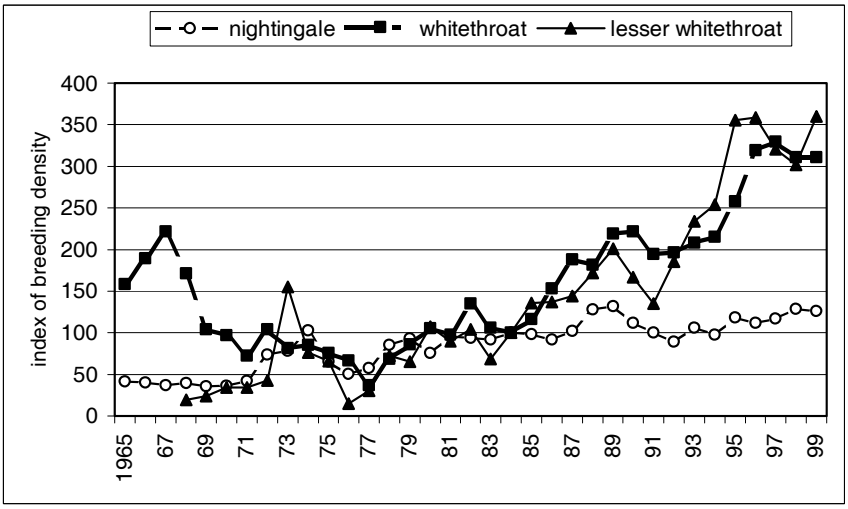

Fig. 17.4. Indexes of breeding densities of birds nesting in scrub in sand dunes of the mainland coast of Holland (the index of 1984 is set as 100). Scrub encroachment was profitable but for these migratory species but conditions in wintering areas always play an additional role. The decline in the whitethroat (*Sylvia communis*) before 1970 was probably influenced by the drought in the Sahel, which is the northern part of the whitethroats wintering grounds. (Data from de Nobel et al. 2001)

NV PWN 2001). In prior centuries, the fox had been exterminated, but between 1968 and 1980 the dunes were recolonized (Mulder 1992) and the population increased rapidly, also because there was (virtually) no hunting. Despite the fact that predation on eggs and chicks of these ground-breeding species was observed, it is not likely that predation was the *only* actual cause of the decline in numbers. In a large part of the Dutch dune reserves, the foxes are not strictly nocturnal and roam around in day time. They roused breeding gulls, ducks, curlews and other nesting ground-breeders so frequently that the birds just deserted their breeding grounds. The most probable explanation for the disappearance of meadow birds is that, the habitat already being deteriorated, nest-predation and disturbance acted as an extra stroke but it is impossible to determine the relative importance of all negative factors. A complex number of factors also affected the decline of some filter-feeding ducks in the Amsterdam Water Supply dunes. The impacting crash in the total number of the most common duck species (Fig. 17.5), frequently lead to instantly blaming the fox. However, a closer look at the species separately shows that shoveler and teal were already decreasing in numbers long before the fox arrived (Fig. 17.6). The banks where they used to forage were gradually overgrown by reed and cattail. The disappearance of foraging opportunities made the area unsuitable for breeding (Baeyens et al. 1997). In summary, the decline of numbers of meadow birds in the main-

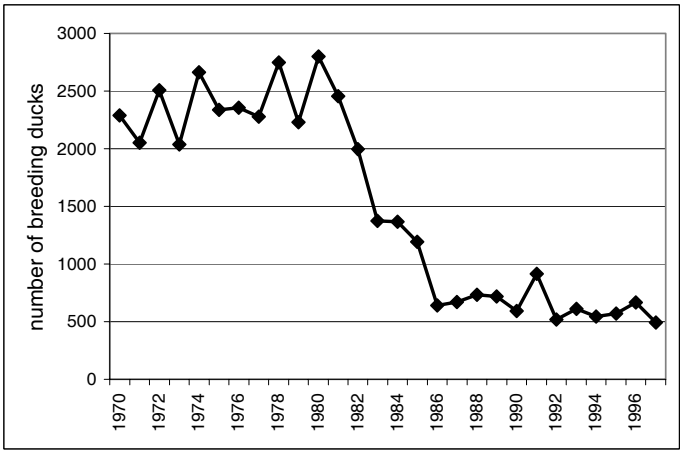

Fig. 17.5. Total number of breeding individuals of ducks in the Amsterdam Water Supply Dunes. The graph indicates an addition of numbers of mallard (*Anas platyrhynchos*), shoveler (*Anas clypeata*), teal (*Anas crecca*), gadwall (*Anas strepera*), shelduck (*Tadorna tadorna*), tufted duck (*Aythia fuligula*) and pochard (*Aythia ferina*), which are the most common breeding duck species in this area. In 1980, the first fox dens were discovered and the population increased very fast in 1981–1984. (Data from Vader, in Baeyens et al. 1997)

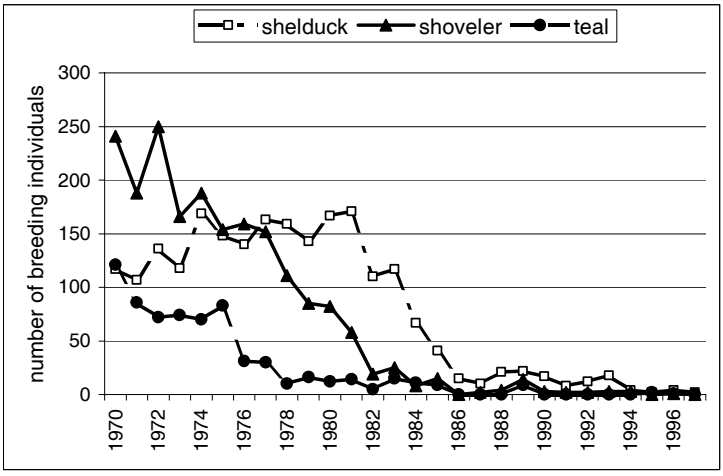

Fig. 17.6. Number of breeding individuals of three species of filter-feeding ducks in the Amsterdam Water Supply Dunes. The decrease in breeding density of shoveler and teal shows a more or less gradual course, starting before the increase in fox numbers since 1980. The filter-feeding species had less and less foraging opportunities as the seepage ponds were gradually overgrown with reed and cattail. The steep drop in shelduck numbers indicates that shelduck probably suffered more from fox predation because they breed in burrows where they are easily traced on smell (Data from Vader, in Baeyens et al. 1997)

land dunes of The Netherlands was thus caused by two main factors: an accelerated landscape succession paralleled by fox disturbance.

Ground-nesting birds and colonial breeders are also vulnerable to predation. In the German Wadden Sea, predation is the main cause of hatching failure for the black-headed gull, the oystercatcher (*Haematopus ostralegus*), the black-winged stilt (*Himantopus himantopus*) and several tern species (Thyen et al. 1998). Aerial predators like gulls and Corvids are sensitive to joint anti-predator defence. When these predators try to approach the nests, all the breeding birds respond together by chasing them away collectively and hence, the chance that eggs or chicks are taken away by gulls or corvids is minimal. Hatching failure is chiefly attributed to predation by night-active mammals like red fox, brown rat (*Rattus norvegicus*), and to a lesser extent to mustelids and hedgehogs (*Erinaceaus europaeus*). Foxes and brown rats have shown recent population increments in almost all European countries resulting in a greater impact on prey species than 30 years ago (Tucker and Evans 1997). For instance, in the mainland coast of The Netherlands, the fox was able to sweep away thousands of gulls in just a few years (Baeyens 1989; Bouman et al. 1991). The gulleries in a mainland dune reserve enlarged gradually in the 1970s: in the innerdunes close to the land side, in the middle dunes with a central position and in the sea barrier, directly behind the beach (Fig. 17.7). From approximately 1980, foxes colonized the dunes and increased fast in numbers. The colonies in the inner dunes were easy to disturb as the foxes had plenty of cover from scrub and shrub. Soon those gulleries were left and birds moved closer to the sea, where the landscape is more open. The effect of fox distur-

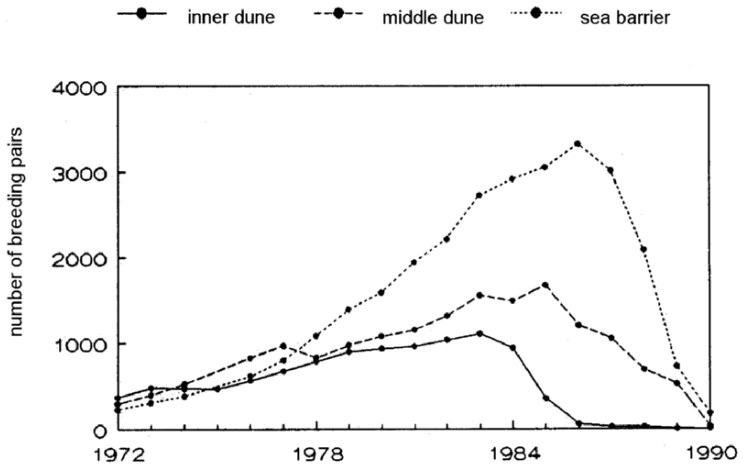

Fig. 17.7. Rise and fall of herring gull colonies in Meijendel, a dune reserve on the mainland coast of Holland. (Bouman et al. 1991)

bance "followed" the gulls and finally the gulleries in the sea barrier were ever so much disturbed that all gulls left the area.

On top of the above, an additional factor played a role: tourism. In The Netherlands, the reduction of working hours from 40 to 36 or even less per week resulted in more visitors having leisure time to spend in nature. In the breeding season, the curlew (*Numenius arquata*) is very sensitive to disturbance by walkers and cyclists (AWD 1981; Vos and Peltzer 1987; Mulder and Swaan 1988). Since approximately 1980, densities of curlew have decreased in all dunes where scrub encroachment and fox occurred concurrently. Despite these two detrimental factors, curlew density increased in two Dutch dune areas after recreation was strongly reduced by closing down foot paths (van Ommering and Verstrael 1987; Slings 1999). Also, in Latvia (Baltic coast), meadow birds disappeared because of the combination of two causes. Dune meadows were no longer mown and overgrown by ruderal vegetation while tourism increased at the same time (Opermanis 1995). Both factors were detrimental for breeding meadow birds. Again it is impossible to quantify how much each separate factor is responsible for the changes as a whole.

The interactions between breeding birds, predators and herbivores that greatly influence vegetation succession can obscure the results of dune management. Sudden changes in food webs can entail domino effects in all links of the chain. Even when the dose-effect relationship seems clear, it is not always possible to reverse a process by altering the dose. In The Netherlands for instance, several mitigating measures against grass and scrub encroachment, like mowing, sod cutting and domestic grazing, do not always restore the breeding densities of birds that disappeared. Earlier, Verstrael and van Dijk (1996) predicted that birds of open dune landscapes would benefit from the reintroduction of stock. However, a recent study in a Dutch dune reserve that has been grazed by cattle since 1990, revealed that the diversity in vegetation structure was improved but that the expected recovery of the bird population failed to occur (Van der Niet 2001). This will not exclude that such measures may be efficient in other dune areas or even benefit other animal groups.

17.5 Coastal Zone Management: Can Animals be Integrated?

When a dune area consists of a strand line with embryo dunes, mobile and fixed dunes, dune valleys and wet slacks, it can host a large number of breeding, migrating and wintering birds: gulls, waders, ducks, and specific passerines. However, when these dune systems are equally appreciated by tourists, they can come into conflict with the avian occupants. Tucker and Evans (1997) have made an inventory of sand dune loss and the adverse effect on birds. Tourism and recreation are by far the severest threat in dunes, espe-

cially in the Mediterranean basin. They affect 47 of the 75 priority bird species, according to the prioritization of SPECs (Species of European Conservation Concern). For example, the estimated loss of sand dunes to tourism over the last 100 years approximates or exceeds 50 % of the total area in the Mediterranean coasts of France, Greece, Italy, Portugal, Spain and Turkey. In the Baltic region, losses from 35 % up to more than 50 % are caused by afforestation.

To segregate tourists and natural fauna, the integrated coastal zone management (ICZM) is now implemented on a worldwide scale (van der Meulen and Udo de Haes 1996; State of Queensland 1999; Texas General Land Office 2001). Coastal functions are relocated in such a way that the economic and leisure demands are restricted and concentrated to protect and conserve the ecological values. In various places in south Europe, Australia and the east coast of the USA, coastal settlements are removed and the building of new tourist resorts is being frozen (Arapis and Margaritoulis 1996; Cosijn et al. 1996). Within the protected dune areas, additional regulations should balance recreation pressure. An example in South Africa shows that conflicts can arise when recreationists show a preference for the most natural and sensitive coastal dunes (Avis 1995). In a comparison of three coastal dune systems, people preferred the one with the highest natural quality and the least commercial development. The recreational capacity must be carefully monitored to ensure the balance between increasing public access and the quality of the natural resources.

Not only birds, but also other vertebrates, have benefited by the conservation policies. The conservation of suitable and tourist-free habitat for smaller and less mobile vertebrates is relatively easy to achieve because their home ranges are relatively small. Rare species of snakes, lizards and toads are or can be successfully protected by isolation from human disturbance (Economidou 1996). In California, for example, habitat conservation and isolation is sustained by predator control (California Department of Parks and Recreation 1998; US Fish and Wildlife Service 1999). Enlarging suitable breeding habitat and relocating lizards at a greater distance from human settlements reduces predation by domestic cats on sand lizards (*Lacerta agilis*) at the Sefton coast in Great Britain (Larsen and Henshaw 2001). In the same British dune reserve, natterjack toads (*Bufo calamita*) are favored by removal of sea buckthorn, excavation of breeding pools and fencing to prevent trampling (Simpson et al. 2001). Zone management is thus applied on two scales: the regional conservation of the dunes as a whole and the local segregation of animals and humans by fencing off. A similar small-scale zonation serves the protection of nesting sea turtles (*Caretta caretta* and *Chelonia mydas*) on Greek beaches (Poland et al. 1995). Zone management on a larger scale can be effective for breeding birds. Breeding success of terns and plovers in New Jersey increased definitely since birds and recreationists have been separated by wardening, posting and fencing (Burger 1995).

For three animal groups, however, coastal zone management does not prevent the impact on dune ecosystems: seed dispersers, herbivores and predators. In South Africa, bushpocket biodiversity is endangered by numerous alien plant species, of which *Acacia cyclops* causes a widespread and ongoing problem (Kerley et al. 1996). Almost 30 % (10.4 % from *A. cyclops*) of all intact seeds dispersed by mammals and birds are invasive species. In the Dutch mainland dunes, a similar problem is apparent with the once imported American *Prunus serotina*, of which the cherry stones are spread by birds and foxes.

As has been shown, herbivores can upturn the vegetation succession completely, especially in the case of mammals with an apparently infinite reproduction rate, like rabbits and fallow deer. In a coastal dune reserve in San Rossoro (Italy), trapping and euthanizing fallow deer is the only possible method to prevent a complete deforestation (Van Breukelen, pers. comm.).

The abrupt increment of a predator population has its effects way beyond any zonation, as is illustrated by the reappearance of the red fox and the disappearance of gull colonies in the mainland coast of The Netherlands. The Dutch coast, however, extends northwards over the West Frisian islands in the Wadden Sea and southwards over the Zeeland islands. So far, these islands have not yet been reached by the fox. It is not surprising that large numbers of the herring gull and the lesser black-backed gull (*Larus graellsii*) have emigrated from the mainland dunes to these fox-free islands. These graphs

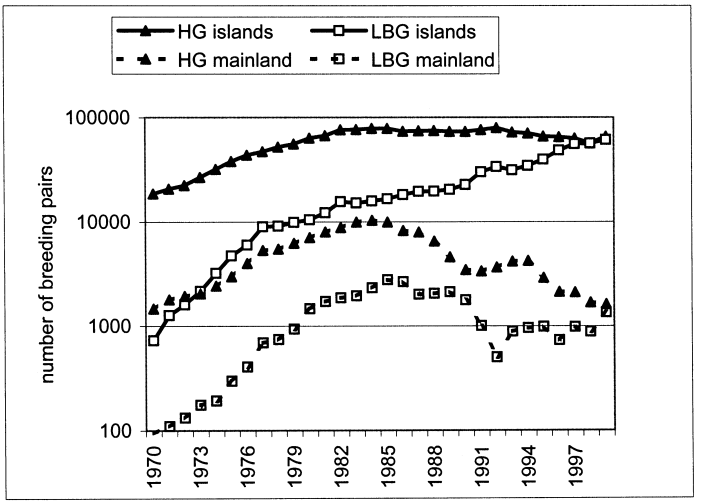

Fig. 17.8. Numbers of breeding pairs of Herring gulls (HG) (*Larus argentatus)* and lesser Blackbacked gulls (LBG) *(Larus graellsii)* on the mainland coastal dunes of Holland and on the dunes of the islands of Zeeland (south west of the mainland coast) and the Wadden Sea (north and north east of the mainland coast) (Data from Spaans 1998, completed and adapted by A.J. van Dijk, SOVON)

(Fig. 17.8) illustrate the impact of the reappearance and dispersion of the red fox on the mainland coast of Holland since the late 1960s. Until 1975–1980, gull numbers were increasing. Because foxes started to disturb the gulleries in the mainland dunes, one after the other disappeared. Some of them moved over to flat roofs of apartments and other large buildings at the seaside, which explains a great deal the remaining figures on the mainland coast. Others moved to the fox-free islands; many new gulleries were established just in the same period as they disappeared out of the mainland dunes.

So far, the increment in gull numbers has not produced unexpected effects in the existent island ecosystems but in theory the development of a predator population can indirectly affect dune areas that are miles away. With periodic monitoring of population dynamics and interspecific interactions, it is possible to assess the effect of such shifts in distribution. Eventually local management plans are needed as additional protective measures where new bird colonies are becoming established.

Coastal zone management is a useful instrument to protect sensitive and rare dune animals but it provides no safety measure against major changes in dynamics and against the sudden appearance or disappearance of essential links in the food chain. In that case, managers have to take specific additional measures, and still these measures are often not more than a continuous treatment of symptoms rather than of causes. Another choice is to accept the events and to monitor the impact on the ecosystem. In either situation, disturbed or not, monitoring of populations and their biotic interactions remains the crucial base for future decisions made by managers, NGO's and governmental institutions.

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