International workshop on the Management of Dune Polder and Dune Marshland Transition Zones

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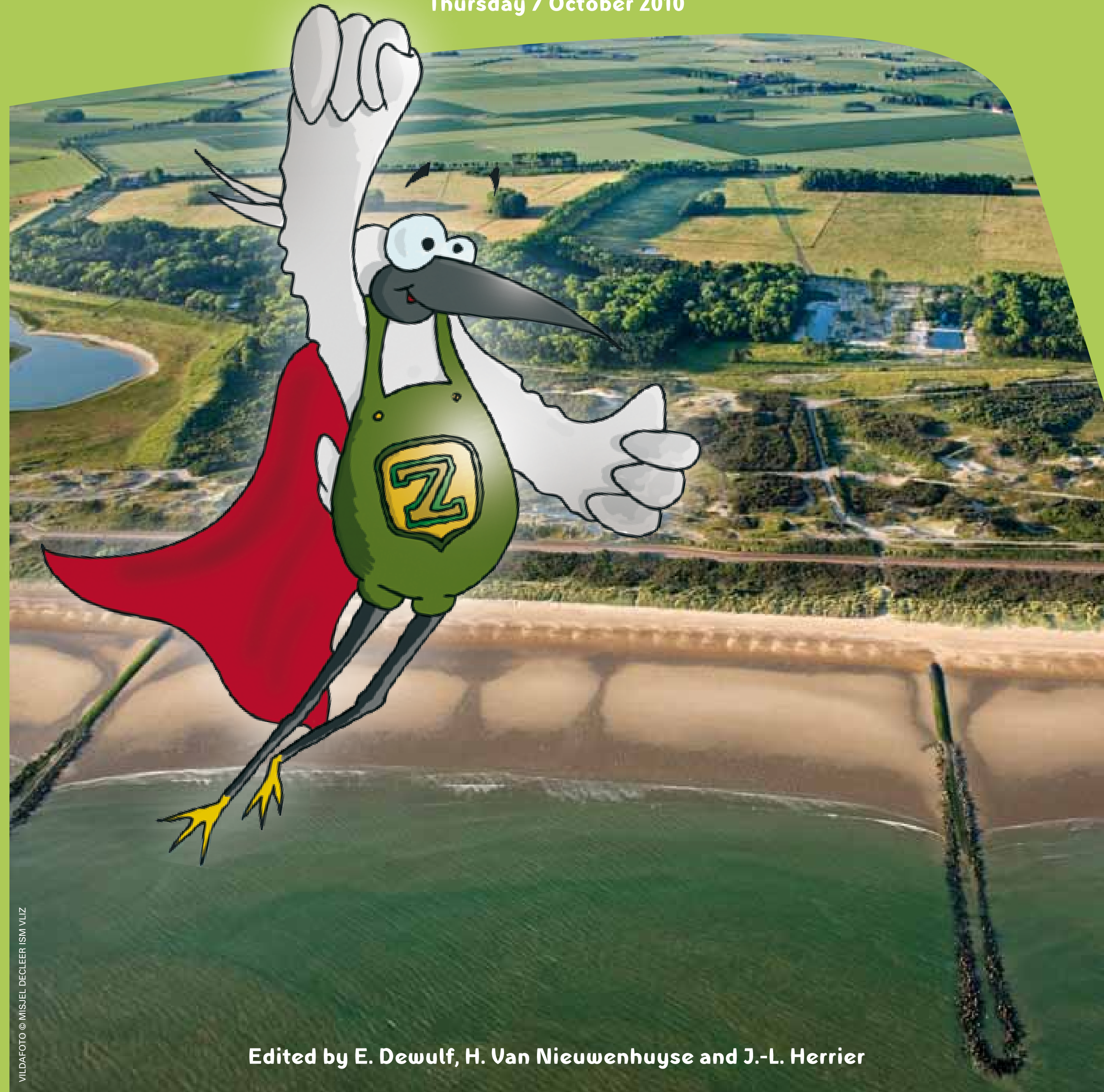
PROCEEDINGS

Pavillon du Zoute, Knokke-Heist (Belgium)
Thursday 7 October 2010



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FOREWORD

The ZENO LIFE nature project (2007-2010) focuses on the restoration of natural habitats in the Zwin Dunes and Zwin Polders nature reserve in Flanders. This includes one of the largest transition zones between coastal sandy dunes and clayish polders on the Flemish coast. Much of this transition zone is a former beach plain that was embanked during the second half of the 19th century.

Like the adjacent and still active tidal flood plain of the Zwin, the Zwin Dunes and Zwin Polders site is in the south-westernmost part of the estuarine complex of the rivers Scheldt, Meuse and Rhine, which is mostly located on the territory of the Netherlands. A project site consisting largely of transitional zones between dunes and polders or salt marshes and located at the border-straddling nature area of the Zwin region inspired the Flemish Government's Agency for Nature and Forests to host an international workshop on the management of dune polder and dune salt marshland transition zones.

Coastal conservation and nature management is often focused on the restoration or maintenance of habitats located in clearly defined physical environments, such as sandy beaches, shingle beaches, sand dunes and salt marshes. Transitional environments, especially between coastal dunes and their hinterland, are often disregarded, because of their mostly rather banal appearance and the fairly intensive human use. Nevertheless, these transitional environments are not only indispensable to the spatial coherence of coastal natural areas, but also have tremendous potential and (at sites degraded only to a degree or not at all) intrinsic importance for biodiversity, as they possess a large number of interacting gradients between physical factors, such as sediment types (sand, clay or peat), lime content, soil acidity, groundwater quality (fresh or saline) and groundwater regime. In the recent past, the lack of recognition for the (potential) importance for biodiversity of transitional environments has led to inappropriate spatial planning and land use, resulting in ecological degradation. Recognition for the importance of transition zones that connect different types of habitat and spatially unconnected sites is expected to increase as connectivity within and between Natura 2000 sites is given more and more attention by the European Commission. The transition belt between dunes and polders constitutes the main, if not the only, spatial connection between the remaining dune sites, especially along the highly urbanised Flemish coast, where remaining dune sites are isolated from each other by built-up areas. A spatial connection typically still has to be developed into an effective ecological connection through appropriate nature restoration measures. Another type of transitional environment even less common than the transition between dunes and polders is the one between dunes and tidal salt marshes. Transitional environments between tidal salt marshes and dunes occur at only five sites along the 155km stretch of coast between Breskens (Netherlands) and Calais (France): Verdronken Zwarte Polder (Nieuwvliet, Netherlands), Zwin (Knokke, Belgium), Bay of Heist (Heist, Belgium), Yzer river mouth (Nieuwpoort, Belgium) and Platier d'Oye (Gravelines, France). Because of the rarity and specificity of the transitional environment between tidal salt marshes and dunes, those sites should also be given special protection and care. This shows the clear need to share experience with experts from other European countries in the field of ecological restoration and nature management in transition zones between dunes and polders and dunes and salt marshes.

The organisers are honoured that eminent scientists and nature managers from the Netherlands, France, the United Kingdom and Flanders are participating in this workshop and so contributing to the advancement of shared knowledge on this subject. Hopefully, this occasion will also play a role in creating an enduring transnational network for coastal nature restoration, development and management.

Marleen EVENEPOEL
CEO
Agency for Nature & Forests of the Flemish Government

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ZENO,
the Little Egret at work in the Zwin Dunes and Zwin Polders Flemish Nature Reserve

Evy Dewulf

Four LIFE nature projects ('ICCI', 'FEYDRA', 'Salt meadows on the Flemish coast' and 'The Uitkerkse polder') have already played an important role in the implementation of the European Natura 2000 network along the short Flemish coastline. Through scientific preparation and a sustained public support campaign were essential to these successes. In addition to their original aims, these projects also had a favourable impact on the conservation policy of the Flemish government and encouraged dialogue between conservationists, local authorities and other interest groups.

Given the experience and results of these successful LIFE nature projects, the time was felt to be right for a fifth one, ZENO (Zwin dunes Ecological Nature Optimisation), a LIFE nature project of the Flemish government's Agency for Nature and Forests.

The project area is the Zwin Dunes and Zwin Polders Flemish nature reserve at Knokke–Heist.

A large part of this area was negatively impacted by human activities to a great degree during the 20th century and grey dunes and wet slacks are now being invaded by scrubs and grasses. The nature values of dune meadows have also decreased, due to over fertilization in the past.

The legally approved management plan for the nature reserve is the basis of this LIFE project. The main objective is the restoration and maintenance of the natural habitats of coastal dunes and their transitions to polders.

I PROJECT AREA

Zwin Dunes and Zwin Polders nature reserve covers an area of 222 hectares of dunes, woodlands and meadows. It is situated between the town of Knokke and the Zwin proper.

Zwin Dunes and Zwin Polders nature reserve is a part of the European Natura 2000 network, because it is situated in the **Special Protection Area BE2501033 'Het Zwin'** in application of **European Birds Directive 79/409/EEC** and, within the framework of **European Habitat Directive 92/43/EEC**, in the Special Protected **Area BE2500001 – Dunes including Yzer river mouth and Zwin**.

Zwin Dunes and Zwin Polders nature reserve consists mainly of rather low coastal dunes and a large fossil beach plain, which was cut off from marine influence in the second half of the 19th century. Before the Zwin Dunes and Zwin Polders were granted protected status as a nature reserve, the area was impacted by human activities such as plantations, the construction of a golf course, a show-jumping arena, an airfield, bunkers, concrete roads and other war-related infrastructure going back to World Wars I and II. This has left visible marks throughout the area. Parts of the dune system in the project area are now being invaded by scrubs and grasses, both of which are superseding grey dunes and wet dune slacks. The nature values in part of the project area have also decreased, because of over-fertilization of the meadows on the fossil beach plain in the last few decades.

Figure 1. Overgrown pond

Figure 2. Show-jumping event called 'Concours Hippique' held annually until 1960

Mindful of the good results and experience of the earlier LIFE nature projects on the Flemish coast and the possibility LIFE projects provide to implement a lot of nature restoration actions in a relatively short period, the Agency for Nature and Forests submitted a new project proposal to the European Commission in 2005. The proposal was approved in the autumn of 2006.

Called ZENO, the LIFE nature project runs **from 31 December 2006 to the end of 2010 (four years)**.

As already stated, ZENO stands for 'Zwin dunes Ecological Nature Optimisation'. This is not a random name: Zeno is the protagonist in 'The Abyss', a novel by Marguerite Yourcenar, which is partly set in the dunes near the Zwin. The mascot of the Zwin Dunes and Zwin Polders has not been chosen randomly either: the Little Egret loves to roam the creeks and forage for food in the brackish marshlands and polder fields, and feels completely at home in the Zwin region. The project budget is **€2,537,060**. Fifty percent of this budget will be paid by the Agency for Nature and Forests, the other half by the European Union.

Figure 3. Little Egret

Figure 4. ZENO logo

II OBJECTIVES OF THE ZENO LIFE NATURE PROJECT

The main objective of the project is **the restoration and maintenance of the natural habitats typical of coastal dunes and their transitions to salt marshes and polders**. These are the priority habitat of Annex 1 of the Habitats Directive **2130*** 'Fixed dunes with herbaceous vegetation (grey dunes)' and the other EU-protected habitats **1330** 'Atlantic salt meadows (Glauco-Puccinellietalia)', **2190** 'Humid dune slacks' and **3140** 'Hard oligo-mesotrophic waters with benthic vegetation of Chara formations'. The project also intends to improve the prospects of EU-protected species in these habitats, e.g. amphibians such as Tree Frog (Hyla arborea) and Great Crested Newt (Triturus cristatus), and birds such as Avocet (Recurvirostra avosetta) and Bluethroat (Luscinia svecica).

The measures in the project area are recommended in the "Integral perspective and management plan for the Zwin Dunes and Zwin Polders Flemish nature reserve" at Knokke-Heist, with attention for recreational joint use". This provides a detailed description of the methodologies to be used to remedy the damage inflicted on the natural environment, ensure its maintenance after restoration and enable recreation in the area without inflicting further damage.

Figure 5. Tree frog (Hyla arborea)

Figure 6. 2190 Humid dune slacks

The second objective of the project is **communicating with the general public, sharing information and experience** with regard to the restoration and maintenance of dune to polder and dune to salt marsh transition zones in Europe.

III CONCRETE ACTIONS OF THE ZENO LIFE NATURE PROJECT

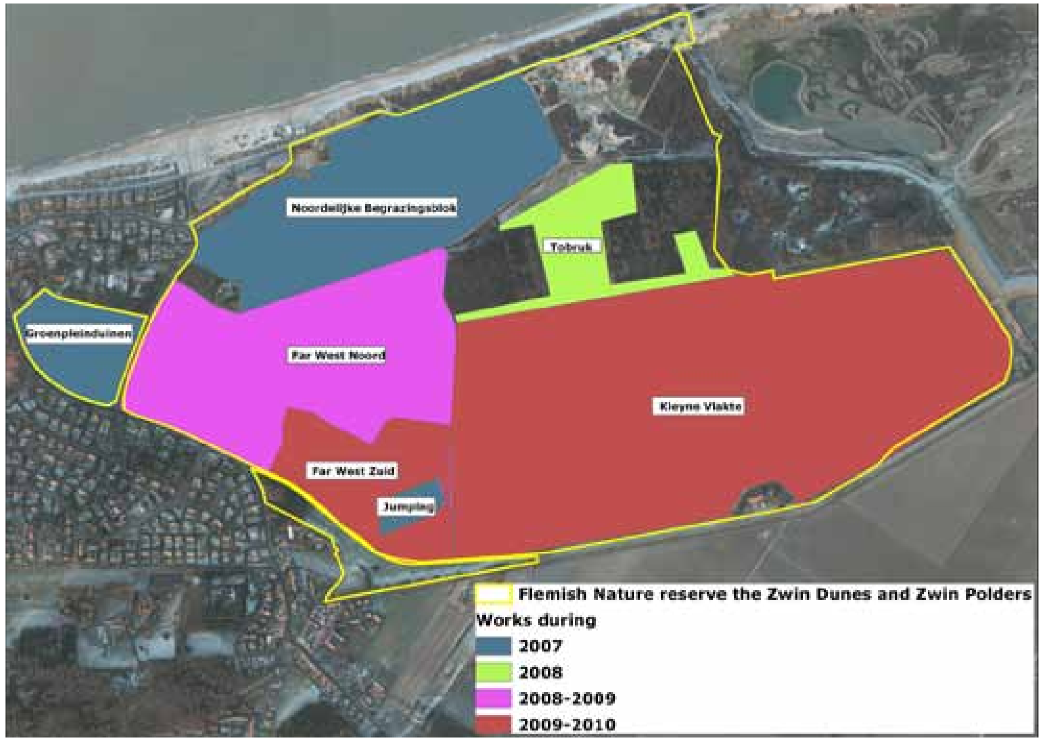

Figure 7. Planning of restoration work during the ZENO LIFE nature project

RESTORATION OF WET DUNE SLACKS AND POOLS

In the past few years, most of the pools and wet dune slacks have been invaded by shrubs and grasses. The shrub will be cleared, existing pools will be re-profiled and some new dune pools will be dug to create an attractive landscape for felworts, orchids, tree frog, crested newt, natterjack toad etc.

Figure 8. Restoration of wet dune slacks in the western corner of nature reserve (Far West) (December 2009)

Figure 9. Cutting sods of grass in the western corner

Figure 10. Restoration of a dune pool of the northern part

RESTORATION OF THE NATURAL DUNE HABITATS IN AND AROUND THE OLD SANDPITS

During the past century, exotic tree species, mainly pine (Pinus pinaster) were planted and sandpits dug in the part of the Nature Reserve called Tobruk. As a result of these human activities, the indigenous dune vegetation was overwhelmed and biodiversity in the area was consequently greatly reduced. Cutting down a number of trees surrounding the ponds will restore a half-open landscape and the connection between two dune grasslands. The sludge will be partially dredged from the sandpits and the angled steep slope of the banks will be smoothed out. This will allow the ponds to receive more light, contributing to much improved water quality. This will all benefit the local fauna and flora.

Figure 11. Restored area in and around the old Tobruk sandpits

RESTORATION OF THE MICRO TOPOGRAPHY OF THE KLEYNE VLAKTE

The southern part of The Zwin Dunes and Zwin Polders used to be a tidal shore plain with salt marshes separated from the sea by a dyke since the 19th century (the International Dyke was constructed in 1872). The eastern part of this region known as the Kleyne Vlakte was levelled in the 20th century for the construction of an airfield. The last plane landed in 1959 in the Kleyne Vlakte, which is now essentially made up of (early fertilized) meadows. A hydrological study was conducted in 2007-09 to determine the options and feasibility of rewetting the Kleyne Vlakte. Restoration work began at the end of 2009 and will be completed at the end of 2010.

Figure 12. Kleyne Vlakte before the work

Figure 13. After the work (April 2010)

Excavation will restore the original landscape in the Kleyne Vlakte of creeks and ditches crisscrossing the land. This will facilitate the creation of wet habitats, so the Kleyne Vlakte will once again sustain the growth of rare water-bound plants and water-dependent animals.

REMOVAL OF OLD INFRASTRUCTURE

A show-jumping arena was built in the Kleyne Vlakte in 1929-30. The Concours Hippique, a famous event, was held every summer until the 1960s. Some old infrastructure was still visible in the landscape. As part of the ZENO LIFE nature project, in September 2007 the concrete obstacles were replaced by a pool, a number of poplars were felled and the route of the historical 'Paardenmarkt Creek' became visible once again in the landscape. This restored the dune grasslands and the half-open character of the dune to polder transition zones.

Figure 14. Show-jumping arena before the work

Figure 15. Show-jumping arena after the work (October 2007)

GRAZING MANAGEMENT

Livestock (cows, goats, horses, donkeys and sheep) used to graze the dunes. Grasses and scrubs started to invade the grey dunes, the dune grasslands, and the wet dune slacks as a result of the absence of such grazing since the middle of the 20th century. That problem has now been tackled by digging out soil, felling trees and shrubs, mowing, and introducing efficient grazers such as Scottish Highland cattle, Shetland ponies and Konik horses. Grazing management with these grazers has had positive results in other dunes along the Flemish coast (restoration of species rich grassland, creation of a mosaic landscape) (Hoffman et al. 2005).

A typical Belgian breed, the Dune Goat is another grazer that has been reintroduced into the Zwin Dunes and Zwin Polders for the first time since the World War I. In this endeavour the Agency for Nature and Forests is working with the Living Heritage Foundation, a non-profit organization working for the maintenance of original stocks of goats, sheep, cattle etc, which are typically very rare now. The Agency also works with the Living Heritage Foundation to introduce sheep in the Kleyne Vlakte. Such methods enable the typical biotopes in the coastal dunes and dune to polder transition zones to be maintained or where necessary restored to a sustainable condition. There will be five grazing units by the end of the ZENO LIFE nature project.

Figure 16. Dune Goat

Figure 17. Scottish Highland cattle

SHARING INFORMATION

Information boards have been erected at appropriate locations during work to inform visitors about current accessibility and alternative routes. They also provide an explanation of the work methodologies and the rationale behind the work.
The general public was informed about ZENO at an evening information session on 29 January 2008. Leaflets, a website (www.lifenatuurzeno.be), press releases and conferences, excursions, information signs and an exhibition during the summer of 2010 are other tools to inform the general public, which is thus full aware of what is going on in the Zwin Dunes and Zwin Polders. This international workshop also enables experience of this kind of management to be shared.

IV CONCLUSION

The five LIFE nature projects on the Flemish coast have had and continue to have effects that exceed their original purpose. They have not only enabled **large-scale nature restoration** in a short time, such as the demolition of the naval bases (ICCI) and the partial deforestation of Hannecartbos (FEYDRA), which would have been very difficult to achieve without EU support. The huge added value of these projects **is the impact they have had and continue to have on the dialogue between conservationists and other actors**. The projects have also boosted Flemish nature management along the coast: the total surface area of coastal nature reserves has increased from 450 hectares in 1996 to 1,213 hectares in 2009.

Figure 18. Simulation of the Zwin Dunes and Zwin Polders

ZENO LIFE is almost completed. The initial results of ZENO LIFE are hopeful: revived dialogue with other actors, which has even resulted in a new EU project proposal, great dynamism in the nature reserve, enthusiastic visitors and residents, and fast implementation of the management plan. The first plants typical of dune-polder transitions have already established themselves. A carpet of Seaside Centaury (*Centaurium littorale*) was already present in the Groenplein dunes in the summer after the work. And, most strikingly, on 7 September 2009 a new plant species *Juncus anceps* was found in the Far West, in the zone where sods of grass were excavated (Leten M. et al. 2010). According to Van Landuyt (2006) this plant species had not been found in Belgium since 1924. However, in 1998 Lambinon et al. contradicted this by stating that it had not been found in Knokke since 1983.
The first Tree Frogs (*Hyla arborea*) in a very long time were also heard in the Zwin Dunes and Zwin Polders during the spring of 2010.

The ZENO LIFE nature project has therefore produced some very hopeful results.

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2

Management of transition zones between coastal dunes and salt marsh or polder area:

experiences from the Belgian coast

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I ABSTRACT

Transition zones between different landscape units are often of key interest to nature conservationists. This is due to their specific environmental conditions e.g. groundwater seepage or gradients in soil texture and soil moisture, which contribute to specific and high biodiversity. Such transitional situations also occur at the fringes of coastal dunes e.g. the sandy dune substrate runs into the clayey soils of the adjacent polders and freshwater conditions of dunes may run into the salty environments of beach or salt marsh. Three main types of transition zone are present along the Belgian coast: 1) between dunes and polder; 2) between dunes and active salt marsh; and 3) between dunes and (former) estuaries or beach plains. Geology, history, soil, hydrology and biodiversity of these types are discussed here.
Currently, little of the natural situation remains. Apart from some parts of the beaches, most of the dune transition zones are heavily affected by human activities such as urbanization, drainage or intensive agriculture. Also conservation interest in these zones is only a recent phenomenon. It was stimulated by a landscape ecological study of the Belgian coast in the late 1980s and the legal protection of some transition sites in the early 1990s. Since then, at least 14 restoration projects have been started in dune transition zones scattered along the Belgian coast. Nearly all are financed by the Flemish government, often with European co-funding. One project is carried out by the province (West-Vlaanderen). In the planning phase, special attention was paid to the hydrology of these sites.
The results of these projects vary so far. Short-term ecological potentials are limited at some sites, because of severe disruption to hydrology. In these zones, a fundamental change in the polder drainage system is required but this has broad public implications. A crucial element in restoring the target flora is the soil seed bank. Plant species of conservation interest have appeared at several restored sites, including a number of species not currently or even historically found in the coastal area. In early stages of vegetation development, however, productive species tend to dominate and can easily outcompete the often vulnerable seed bank appearances. This entails major challenges for management. Relatively little is known about the fauna of the dune transition zones. So far some results for common species groups such as birds, amphibians, dragonflies, butterflies and grasshoppers are mentioned. Finally, the need for ecological monitoring of the projects is stressed.
Coastal dune; salt marsh; transition zone; polder; ecological restoration; soil seed bank

II INTRODUCTION

Transition zones between different landscape types are valued by many ecologists as important habitats for their characteristic plant and animal diversity. This is related to specific environmental characteristics such as soil gradients, groundwater seepage and combination of habitat types. Similar situations occur at the fringes of coastal dunes. The sandy substrate and freshwater conditions of dunes turn into the clayey soils of the adjacent polders or the salty environments of beaches or salt marshes. However, most dune-polder transition areas suffer from intensive agricultural use (*fig. 1*).

Figure 1. One of the last uninterrupted transition zones between semi-natural Young Dunes and agricultural polder (Koksijde, Belvédère)

In this paper, we discuss the possibilities and limitations of restoring dune transition zones along the Belgian coast. First we will give a description of the Holocene evolution of the coastal dunes and the human impact on the recent landscape evolution, followed by a general analysis of some abiotic conditions in relation to the restoration of these sites, i.e. hydrology and some soil related aspects. The emphasis is on discussing the most important dune transition sites along the Belgian coast and restoration projects that were executed over the last decade. Our conclusions may be relevant and applicable to other similar situations in Northwest Europe.

We define restoration as an attempt to restore destroyed habitats to their original state. Here, it mostly concerns changing the present state of agriculturally intensified sites into a more valuable, former state. Inherently, this preferred state should be described using the concept of target plant and animal species and/or target communities. The effects of restoration activities can only be measured and evaluated after targets have been set. Monitoring is a very important tool for this kind of evaluation of the effects of ecological restoration. Monitoring will tell us if the targets are met within a given period of time. If this is the case, restoration is considered successful and the main ecological relationships in the particular system are clear. If a restoration project fails, it means that the relationships are not clear.

III CHARACTERISTICS OF THE BELGIAN DUNE TRANSITION ZONES

SITUATION

Sandy coastal barriers with extensive back-barrier basins prevail from the Strait of Dover to the western Danish coast, , intersected with numerous estuaries e.g. Scheldt, Rhine, Meuse, Weser and Elbe and the tidal inlets and barrier islands of the Wadden Sea. There are dunes along the entire 66km of Belgian coastline, but their history and macro-morphological appearance differ significantly. There is a 1.5-2km broad dune belt between the French-Belgian border (De Panne) and Nieuwpoort (IJzer estuary) . It mainly consists of 'Young Dunes', mostly characterized by large wind shaped parabolic dunes and slacks. Dune heights may be as much as 30m above sea level (e.g. Hoge Blekker, Koksijde). Only a narrow dune ridge is generally present between the IJzer (Middelkerke) and Zwin estuaries (Knokke) , but near to the Zwin estuary the dune system broadens again. In general, dune heights are lower compared to the western coast and parabolic dunes are lacking or less distinct. In the vicinity of Nieuwpoort (IJzer estuary), De Haan and Knokke, complex dune systems are found that are ontogenetically linked to actual or fossil estuarine systems. Primary lime content decreases from up to 10% in the west to less than 3% in the east (Depuydt, 1972).

Locally, remnants of older dune belts or coastal barriers remain on the surface. This is the case at De Panne (dunes of Cabour-Garzebekeveld and their French counterpart "Les Dunes Fossiles de Ghyvelde", together with some small spots dispersed in the maritime plain), Oostduinkerke-Nieuwpoort (Santhooft), Middelkerke (Schuddebeurze), Bredene/De Haan (D'Heye) and the now completely cultivated dune system of Vlissegem. However, only the dunes of Cabour still have a clear but rather low dune topography (heights up to 8.5m TAW).

Because of urbanization only about 3000 ha of the original 7500 ha of the once almost continuous Belgian dune belt is preserved (Provoost, 2004). Moreover, considerable parts of the remaining inner dunes are cultivated. *Fig. 6* shows the most important dune sites along the Belgian coast as well as the principal remaining dune-polder and dune-beach transition zones.

HOLOCENE EVOLUTION

The actual position of the Belgian dunes is due to the complex evolution during the Holocene. When sea level started to rise after the Last Glacial Maximum (Weichsel) coastal barriers formed, creating tidal basins behind them. Around 7500 BP, this barrier stretched from the current village of Adinkerke to about 15km northwest of the current city of Knokke (Mathys, 2009). The salt marsh vegetation of the coastal tidal plain gradually developed into a coastal reed marsh vegetation which, as a consequence of a further decrease in the rate of relative sea-level rise, would cover the whole coastal plain for several thousand years, producing a thick peat layer (Baeteman, 2007).

The oldest dunes visible in the present landscape are remnants of the coastal barrier formed between about 5000 and 2500 years BP. They are probably the same as those developed on the beach ridges ("strandwallen") of the Dutch coast. These dunes are situated in the western part of the coast (Cabour-Adinkerke, De Panne). Eastwards, the coastline has retreated up to several km since then, destroying any old dune barrier.

Between 2800 and 2400 cal BP a renewed tidal system was installed in the back-barrier area of the western Coastal Plain (Mathys 2009). This was probably induced by the deepening of older channels due to increased rainfall and excessive run-off from the continent, related to climatic change around 2800 cal BP and to human activity (e.g. deforestation, peat digging). It was not until 1400-1200 cal BP (550-750AD) that sediment supply and tidal prism achieved equilibrium with the sea-level rise. At that time the major part of the coastal plain had evolved again towards an active salt marsh system (Baeteman, 2007). Two areas with now decalcified dunes, Schuddebeurze/ Santhooft in Westende-Nieuwpoort, and D'Heye/Vlissegem in Bredene-De Haan probably established during this period.

From the early Middle Ages onwards, human interventions such as the construction of embankments had a significant impact on the evolution of the coastal landscape. The active salt marsh was gradually reclaimed and converted into polder pastures and arable land. At the same time the natural landscape of the dunes gradually turned into a semi-natural landscape with livestock and rabbit grazing, scrub cutting etc. This led to the slow but irreversible degradation of the dunes from the 12th century onwards (Augustyn, 1995). Most of the actual Belgian dunes were formed in different dune building phases during the past 1000 years within this human-dominated environment. The more recent stages consisted of active parabolic or crescentic dunes moving mainly southeast and sometimes covering agricultural land or small hamlets in the dune-polder transition zone. Attempts to stop the sand drift by planting marram grass and a woodland fringe have probably enhanced the local development of high inner-dune ridges and sharp dune-polder transition zones (e.g. between the French border and Koksijde) (*fig. 2*).

Figure 2*. The high inner dune ridge and sharp dune-polder transition zone characterized by a narrow fringe of woodland and meadows with coppiced willows at De Panne ('Zwarte Duin') (Massart, 1912).*

A specific situation occurred between the current village of Oostduinkerke and the town of Nieuwpoort. In the 8th century a tidal channel linked to the IJzer system was situated in this area. Along its southern edge a belt of low dunes were established and the channel developed into a large beach plain. After the reclamation of the most inner parts (Lenspolder) with the construction of a coastal embankment (Groenendijk) c. 1300 AD, the seaward part became partly covered with mobile dunes. The remaining parts of the beach plain and adjacent low dunes developed into one of the most particular but complex dune transition zones along the Belgian coast, including the 'Doolaeghe' site which is now part of the Ter Yde nature reserve (Koksijde) (*Fig. 3*).

Figure 3. The historical inner dunes area and gradual dune-polder transition zone between Koksijde and Nieuwpoort as mapped by Cassini (1756).

During the 15th century severe north-westerly storms almost completely destroyed the eastern part of the coastal barrier. The large island of Wulpen, in the NE, completely submerged into the sea, causing irreversible hydrographic changes in the Scheldt estuary. As a consequence, the coastal barrier retreated to its current position and the Zwin channel gradually silted up (Mathys, 2009). Construction of embankments sped up this process. As a result, several beach plains and dune ridges were formed in this area.

HYDROLOGY

The sandy deposits under coastal dunes act as a freshwater aquifer. In Belgian dunes, the groundwater is largely charged by infiltration of precipitation, while discharge is caused by superficial runoff, groundwater outflux and evapotranspiration. The charge-discharge equilibrium is reflected in certain hydrological conditions typical for each site. Groundwater pressure heads in the phreatic layers are largely determined by the amount of infiltrating water, the dimensions and composition (lithology) of the aquifer and the groundwater levels along the boundaries. Seaward, these levels are relatively constant at about 4.20m (east) to 4.35m (west) TAW, the sea level at average high tide. The frequency of the diurnal tides is apparently too high to have a draining effect on the groundwater system, due to the inertia of groundwater flow. The monthly

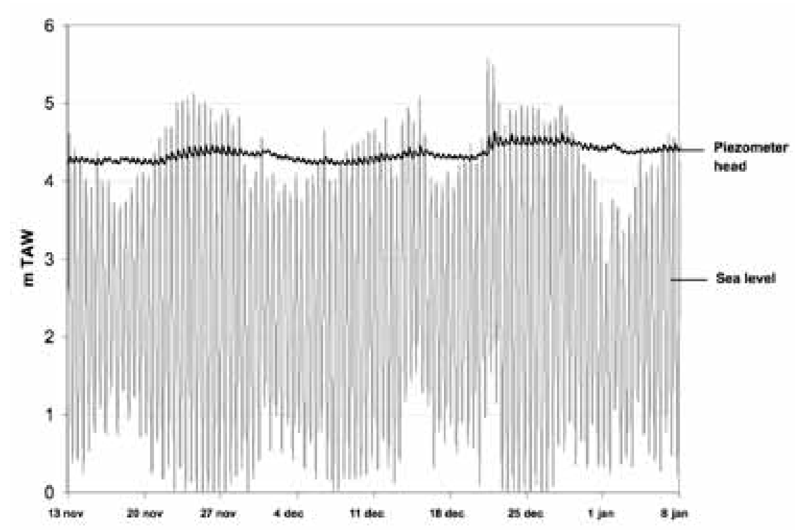

Figure 4. Groundwater levels and fluctuations at the dune-beach transition in Nieuwpoort-IJzermonding (2003-'04).

high-neap tide cycle is, however, clearly reflected in the behaviour of sea bound piezometers (*fig. 4*). Therefore, contact with intertidal areas has a stabilizing effect on dune groundwater fluctuations. In the fairly natural situation of about 1200 years ago, these boundary conditions would have been found at both seaward and landward margins of the dune system, as it was surrounded by either sea or salt marsh. During periods of marine recession, e.g. 7500-2800 cal BP, inner dune ridges were in contact with fresh coastal marshes. Groundwater levels must have been at least as high as in an intertidal situation but fluctuations were probably more pronounced due to evapotranspiration. Most probably, the historical inner dune ridge would have been a very wet zone, as additional groundwater seepage occurred from the dune aquifer. At present, dunes are in contact with the intertidal zone only along beaches and in the few remaining active salt marshes. In most of the landward zone, dunes are in contact with reclaimed salt marsh or polders. This strongly affects hydrology in the adjacent dunes, not only by lowering the groundwater table due to drainage but also by increasing groundwater fluctuations up to about one meter on a yearly basis. Although mostly captured by the artificial drainage system, the iron and lime rich seepage water may still have a positive effect on water and grassland quality in the dune-polder transition zone (*Fig. 5*).

Figure 5. Berula erecta often indicates seepage influence in ditches and pools of the dune-polder transition zone.

SOIL CHARACTERISTICS OF THE DUNE TRANSITION ZONES

The dune-polder transition soils (D series) mostly form a strip with a width of a few hundred meters. Only at a few places they do cover larger areas. In total, the D series cover an area of 950 ha, 500 ha of which is not urbanized (Provoost & Hoffmann, 1996). The Belgian soil map distinguishes two main types: dune sands (Da) and silt bearing sands (Db) at varying depths (> 60 cm) usually covering polder sediments (tab1). In the neighbourhood of the IJzer estuary dune sand can cover coarse sandy beach deposits. The silt bearing sands are marine sediments, indicating rapidly changing coastlines with limited aeolian reworking. In fact, the Db soils are strongly related to the main polder landscapes. Indirectly, their spatial distribution is often related to areas with groundwater seepage and at least partially overlaps with the (former) presence of wet grassland (De Raeve, 1991). The dune sand transition soils are usually the result of drifting sand covering polder sediments.

The transition soils, specifically the Db soils, generally exhibit pronounced fine-scale spatial variation. The thickness of the sand layer can differ over a short distance and the texture can abruptly turn from sand into silt-bearing sand or locally even to clay. Furthermore, the texture of the polder deposits themselves may change from coarse sand to heavy clay. As a consequence the groundwater regime and quality show significant spatial variation.

The transition soils have always been cultivated and hence often have a thick organic topsoil. Moreover, when the transition soils are part of cultivated polder fields they are generally also highly fertilized and undergo supplementary drainage.

Theoretically, areas with transition soils are very promising for nature restoration. However, given the degraded conditions, environmental engineering will often be necessary. This has to be done in both a rigorous and careful way. Excavation and sod cutting are the most essential initial measures to be taken, while subsequent recurrent management should focus on fine-scale differentiation in the plagioclimax state. Larger management units are preferred, including dunes and polders (De Raeve, 1991).

TAB. 1.DUNE SOIL TYPES ACCORDING TO THE BELGIAN SOIL MAP (Moormann, 1951)

Series	Type
A High dunes	-
B Dune soils	B1 Dry
	B2 Moist
C Levelled	C1 Dry
	C2 Moist
D Transition soils	Da Dune sand
	Db Silty sand

RECENT LANDSCAPE CHANGES

History of human impact

The dunes in northwest Europe were used as rabbit warrens, for livestock grazing, shrub and tree cutting, sod cutting, etc since their formation (Provoost et al., in press; De Smet, 1961). According to several authors, the over-exploitation of the landscape was a main cause of sand drift from the 16th to the 18th century. Several hamlets disappeared under drifting sand during this period, also along the Belgian coast (De Ceunynck, 1992). From historical sources, such as the

18th century 'de Ferraris' map, we can deduce the former general composition of the dune landscape. In this period the landscape consisted of a broad dune belt with large west-east oriented dune slacks. Outside of the dune polder transition zone, there is no trace of arable fields. Where a high and active dune ridge borders the polder, a fringe of wooded parcels and rows of trees are visible on this map, indicating efforts to prevent dunes invading the polder.

After the French revolution, both the population and agricultural exploitation increased. By the end of the 19th century 270ha of arable fields were scattered over the western coastal dune belt (Van Aerschot et al., 1992). The associated cattle and donkeys grazed in the commonly used dunes and shrubs were cut regularly to provide fuel. Massart (1912) has left us a series of high-quality pictures illustrating the largely agropastoral landscape of the early 20th century. At the time the dunes along the Belgian coast were almost devoid of high shrubs and trees, with the exception of some plantations, e.g. at the foot of the high inner dune ridge.

New settlements and road infrastructure appeared in the same period. Tourism expanded between the wars (1918-1940) and especially in the decades immediately following WWII, and as a consequence an ever increasing area of the dunes became urbanized, destroying and fragmenting the semi-natural dunes. Meanwhile, the first attempts were made to protect characteristic dune sites. In 1935 the current De Westhoek Nature Reserve was the first to be protected as a landscape. The transition zone with the polders retained its often rather extensive agricultural character until the 1960s, but, as a consequence, was not considered for protection.

Final decline of the dune transition ecosystem – towards a conservation policy

Because of the growing tourist and urban pressure on the coast, and sometimes also because of the stronger protection of the remaining 'real dunes', development for tourism purposes started focusing on the inner dunes and the dune-polder transition zones (leisure parks, camp sites etc) by the end of the 1960s intensified agriculture had also had a very negative impact on the biodiversity of the remaining dune-polder transition sites.

In fact, conservational interest in dune transition zones is only a recent phenomenon, stimulated by landscape ecological studies of the Belgian coast

in the 1980s (De Raeve et al., 1983; De Raeve, 1991) and the legal protection of most remaining transitional areas in the 1990s (Duinendecreet). The ideas on restoration were brought together in a policy vision in 1996 (Provoost & Hoffmann, 1996).

Since then, several large or small restoration projects have been set up in at least 14 dune transition zones scattered along the Belgian coast. Nearly all are financed by the Flemish government, often with European co-funding (LIFE). One project is carried out by the province (West-Vlaanderen). In the planning phase, special attention was paid to the hydrology of these sites.

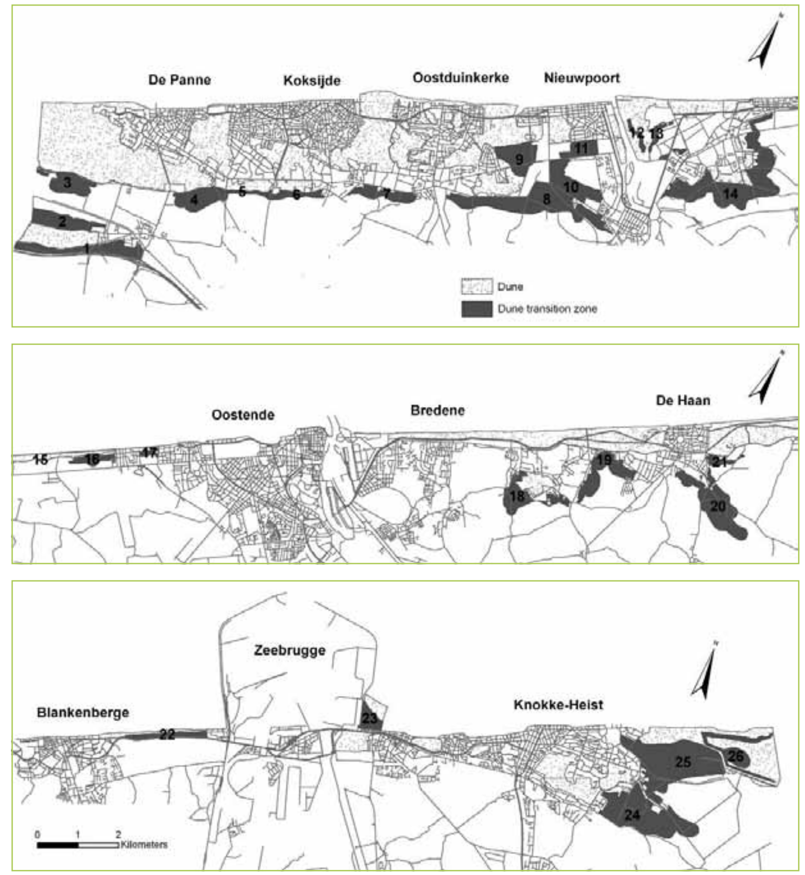

Figure 6. Location of dune areas and transition zones along the Belgian coast.

IV AN OVERVIEW OF SITES AND PROJECTS

1. CABOUR-GARZEBEKEVELD SOUTH (DE PANNE, ADINKERKE)

Type of transition zone:

Gradual, sometimes vague dune-polder transition. 69 ha, 14 ha (Cabour) and 21 ha (Garzebekeveld, including Wachtkom Molenhoek) of which are subject to nature management (*fig. 7*). Historically a very wet transition zone between the Ancient dunes of Adinkerke and De Moeren/ Buitenmoeren, a former lake and marsh area, reclaimed at the end of the 18th century.

Figure 7. After reprofiling of a broad zone along the bank of the Ringsloot interesting marsh vegetation developed under an extensive grazing regime (Wachtkom Molenhoek).

Abiotic conditions:

- *Soil types: C1 and C2 (tab. 1) and some Da and Db (so called transition soils), in total 45 ha.*
- *Hydrology: dune seepage water occurs locally near the southern dune ridge, but also in de low-lying Moeren (Zuidmoerse hoek). Severe impact of the deeply drained De Moeren and Buitenmoerenon the hydrology of the transition zone.*
- *Topography: flat or weak slope towards the low dunes of Cabour; most parcels have been levelled or even excavated*
- *Former land use: pasture, disused sand-quarries or rarely arable field*

Historical reference:

- *Ancient floristic data are very rare; a mid-20th century record of Radiola linoides might be situated here. Before nature restoration, a small population of Schoenoplectus tabernaemontani still existed in a meadow pond and rare Trifolium species were still present in road verges etc.*

Problems to be solved:

- *Polder drainage effects (De Moeren/Ringsloot, Koekuitvaart)*
- *Destruction and fragmentation of dune-polder transition habitat as a consequence of highway construction*
- *Often high nutrient charge in upper soil layer*
- *No adequate nature management until c. 2000, half of the area still remaining in private hands.*

Ecological restoration:

- *Projects: reprofiling of the Ringsloot bank in Wachtkom Molenhoek (project related to the construction of adjacent A18 highway), execution: c.2000; local sod-cutting, excavation or restoration of ponds, reprofiling of ditch banks, etc as provided for in nature management plan (approved 2007), execution: 2009-2010.*
- *Scientific basis: floristic inventory, vegetation description & mapping. Several years of detailed hydrological measurements and some soil mapping.*
- *Target species – target communities: species mix of wet polder grasslands (mainly Lolio-Potentillion elements), nutrient poor wet and dry (dune)grasslands (Festuco-Galietum, Cynosurion and Calthion elements) and mesotrophic pools.*
- *Restoration tools: local excavation of the soil for the purpose of obtaining the low sloping bank of the Ringsloot and local sod cutting using large machinery. A few parcels of diversified woodland have been planted. Other nature restoration measures include annual mowing of some specific spots in order to reduce soil nutrient charge and Holcus dominance.*
- *Recurrent nature management: mainly seasonal grazing (cattle and horses) with additional mowing; extensive arable farming for birds and weeds on one small parcel.*

Results:

Some target species established in areas with wet excavated soils and on a re-profiled drainage channel bank: Juncus subnodulosus, *J. gerardii, J. compressus, J. conglomeratus, Carex distans, C. flacca, Trifolium fragiferum, Schoenoplectus tabernaemontani, Apium graveolens, Berula erecta, Callitriche truncata, Chara* sp.

As a result of sod cutting and/or extensified grazing without fertilizing grassland vegetation with *Trifolium subterraneum, T. striatum, T. micranthum, Vulpia bromoides,* etc established in the dryer parts of most managed parcels; *Primula veris* appeared on the site of former hay meadows at the fringe of De Moeren.

2. CABOUR NORTH (DE PANNE, ADINKERKE)

Gradual dune-polder transition (56 ha), of which 4 ha are recently acquired for conservational purposes. At present mainly pastures and arable fields with some (recent) hedgerows and coppiced willows. The area bordering the Cabour dunes was described as poor grassland or even 'heath' in 1830. No immediate restoration project planned.

3. ZWARTE HOEK (DE PANNE, ADINKERKE)

Type of transition zone:
Complex dune-polder transition zone on a fossil beach plain, with sandy soils on polder clay at the foot of a high inner dune ridge and an isolated sandy remnant of the fossil beach plain or low Old Dune; strongly influenced by a large and deep former sand quarry (artificial lake of 6 ha) and excavated sand deposit zone; 51 ha, 16 ha of which is managed as a nature reserve (*Fig. 8*). Intersected by the polder drainage channel Langgeleed.

Figure 8. Gently sloping bank of artificial lake just after reprofiling (De Panne, Zwartenhoek), with the high inner dune ridge (Westhoek nature reserve) in the background.

Abiotic conditions:

- *Soil types: C1, C2, Da and Db soils in the northern part (18 ha), intersected with clayey polder soils. Locally also artificial (lime rich) sandy substrata due to sand extraction activities.*
- *Hydrology: local discharge of dune groundwater, near southern dune ridge of the Westhoek nature reserve. Upwelling water is mostly evacuated by the Langgeleed, a medium sized polder canal. The water reservoir of the former sandpit has a buffering effect on the seasonal fluctuation of the groundwater level in the neighbourhood.*
- *Topography: mainly flat, very weakly sloping in southern direction*
- *Former land use: pasture, arable field, sandpit.*
- *A particular feature is formed by the artificial environment of a deep lake with very clear water (former sand pit) and dry to wet sand deposition sites.*

Historical reference:

- *19th century: zone adjacent to inner dune ridge wooded (coppice wood), other sandy soils used as pastures.*
- *Very few historical data, e.g. Hydrocharis morsus-ranae (Langgeleed), Althaea officinalis; more recent data on Berula erecta, Trifolium subterraneum, Medicago minima.*

Problems to be solved:

- *Polder drainage effects (Langgeleed, Canal Veurne-Dunkerque)*
- *Direct discharge of sewage water into watercourses, indirect impact of manure.*
- *Destruction and fragmentation of the transitional habitat as a consequence of road and railway construction, recreational urbanization (camping, riding stables, shops).*
- *High nutrient charge in upper ground layer as a result of current or former agricultural use*

Ecological restoration:

- *Project: execution of nature management plan (2007) since 2008..*
- *Scientific basis: floristic inventory, vegetation description & mapping. Several years of detailed hydrological measurements + some soil mapping.*
- *Target species – target communities: According to local abiotic conditions: wet grasslands (mainly Lolio-Potentillion elements); nutrient poor humid to dry decalcified grasslands (Festuco-Galietum, poor Cynosurion); calciphilous dune grasslands and dune slack vegetation (Polygalo-Koelerion, Caricion davalianae,Charetalia) in the sand deposit site; reedbeds and marsh vegetation on part of the banks of the lake and Langgeleed. Riparia riparia, Merops apiaster and Alcedo athis were target species for the steep banks of the disused quarry.*
- *Restoration tools: Local lowering or steepening banks along the lake etc to obtain a great variety in bank habitat and give breeding opportunities to breeding birds. Other nature restoration measures include annual mowing of some particular places in order to reduce the soil nutrient charge and Holcus dominance, and the creation of a new meadow pond.*
- *Actual recurrent nature management: mainly grazing (cattle and horses) and annual mowing of parts of the grassland and dune slack pioneer scrub. A part of the sand depot area spontaneously evolves towards Salix scrub.*

Results:

Several target species of dune slack communities established in former sand deposition site: *Carex viridula, Pyrola rotundifolia, Epipactis palustris, Dactylorhiza incarnata, D. praetermissa, Juncus subnodulosus,* together with *Polygalo-Koelerion* elements such as *Anthyllis vulneraria* and *Anacamptis pyramidalis* on the dryer parts. The grassland on decalcified sandy soil evolved towards a vegetation rich in rare *Trifolium* species and *Orobanche purpurea*. The creation of steep banks led to successful breeding of *Riparia riparia*. Just south of the transition zone, excavated temporary pools in a former arable polder field (now part of the nature reserve) were colonized by *Epidalea calamita*.

4. DUINZOOM OOSTHOEK (DE PANNE, ADINKERKE)

Type of transition zone:

Complex dune-polder transition zone with sand covered clayey polder soils at the foot of a steep inner dune ridge and an isolated outcrop of Old Dune partly covered by polder clay. Narrow wooded fringe at the foot of the high inner dune ridge. Intersected by the polder drainage channel Langgeleed. 50 ha, 16.5 ha of which is managed as a nature reserve (*fig. 9*).

Abiotic conditions:

- *Soil types: C1, C2, Da and Db soils (28 ha), interwoven with polder clay soils.*
- *Hydrology: local discharge of seepage water (weakened by the lowering of the water table in adjacent dune) south of the dune ridge, though largely drained by the Langgeleed.*
- *Topography: mainly flat, with fossil dune remains at 5m TAW.*
- *Land use: nature reserve with woodland fringe, hay meadows, grazed grasslands, pools, temporary inundated depressions, etc; agricultural area with fertilized pastures and arable fields.*

Figure 9. In Duinzoom Oosthoek former draining ditches between arable land were dammed and enlarged with a gently sloping bank; arable land was transformed into permanent grasslands.

Historical reference:

- *19th century: broad zone adjacent to inner dune ridge wooded (coppice wood), other sandy soils used as pastures.*
- *No decisive historical records of target species known; a 19th century found of Ophrys insectifera may have been localized in the wooded fringe at the foot of the inner dune ridge.*

Problems to be solved:

- *Polder drainage effects (Langgeleed) and lowering of water table in adjacent dunes (partly due to water extraction).*
- *Direct discharges of effluents into Langgeleed, indirect impact of manure in the agricultural areas.*
- *Nature reserve: diminishing but still high nutrient charge in upper soil layer as a result of former agricultural use.*

Ecological restoration:

- *Projects: VLM-Nature Development Project (1999-2004), provisional nature management plan adopted since 2004, re-evaluation planned in 2011.*
- *Scientific basis: floristic inventory, hydrological measurements.*
- *Target species – target communities: species rich grasslands of Lolio-Potentillion, Cynosurion (permanently grazed units), Arrhenaterion/Calthion (hay meadows) and Trifolium- rich Festuco-Galietum on fossil dune soils. In the historical wooded fringe of the inner dune ridge the conservation and restoration of Alno-Ulmion-forest and hedges is a primary aim.*
- *Restoration tools: Excavation of the soil in order to obtain low sloping banks of the Langgeleed and former parcel ditches; creating or restoring meadow pools; local sod cutting on dune polder transition soils. Annual mowing in order to reduce the soil nutrient charge and Holcus or Cirsium dominance.*
- *Recurrent nature management: mainly seasonal grazing (cattle and horses) and annual mowing (hay meadows). Selective coppicing in woodland fringe, recurrent clearing of hedges and drainage channel banks.*

Results:

In the first years after nature restoration some target species with affinity to *Caricion davallianae, Calthion or Phragmitetalia* established on the denuded sandy soils, in most cases probably originating from a persistent seedbank: *Carex flacca, C. trinervis, C. viridula, C. paniculata, C. pseudocyperus, Euphrasia tetraquetra, Veronica beccabunga, Juncus acutiflorus,* surviving in small populations at best ever since. On dry sandy soil species as *Trifolium striatum* and *Ornithopus perpusillus* established more sustainable populations. In general, however, botanical results are ambiguous. In the depressions and ponds populations of *Triturus cristatus* and *Epidalea calamita* could expand considerably.

5. BELVÉDÈRE (KOKSIJDE)

Type of transition zone:

Geomorphologically intact sharp dune-polder transition zone. 18.6 ha, 6.5 ha of which is managed as a nature reserve (Fig. 10).

Figure 10. Wet hay meadow in Belvédère, with the medieval abbey farmhouse of Ten Bogaerde in the background

Abiotic conditions:

- *Soil types: Da, only in the northernmost part (4.7 ha); polder clay soils in the southern part.*
- *Hydrology: local discharge of dune groundwater, especially in ditches and near dune ridge. The Langgeleed drains this seepage water at least partially.*
- *Land use: nature reserve: hay meadow and non fertilized pasture. Agricultural part: farm grasslands.*

Historical references:

- *19th century: total area used as pasture.*
- *No ancient records of target species known. Small populations of Juncus subnodulosus, Equisetum fluviatile and Berula erecta, indicating seepage influence, existed before nature management in ditches; Triglochin palustre was found in the 1970's in a pasture outside the actual reserve.*

Problems to be solved:

- *Drainage effects of neighbouring polder canal.*
- *Outside nature reserve: lack of adequate nature management.*

Ecological restoration:

- *Project: execution of nature management plan approved in 2000.*
- *Scientific basis: floristic inventory and several years of detailed hydrological measurements.*
- *Target species – target communities: cf. 4. Oosthoek.*
- *Restoration tools: excavation in order to create or restore ponds and profiling the banks of the former draining channels. Other nature restoration measures include annual mowing of most grassland in order to reduce the soil nutrient charge and Holcus or Cirsium dominance.*
- *Recurrent nature management: annual mowing followed by seasonal grazing by cattle.*

Results:

Extension of *Berula erecta, Veronica beccabunga Equisetum fluviatile* and *Juncus subnodulosus* is indicative of the better quality of seepage zones. In the hay meadow, newly established populations of *Rhinanthus angustifolius* (most probably dispersed through management machinery), *Carex distans* and *Dactylorhiza fuchsii* indicate a fledgling rise in quality, but expansion of *Cirsium arvense* and *Holcus lanatus* clearly hampers positive results. The population of *Nympoides peltata* in a meadow pond may be anthropogenic. A nature development project (VLM) in the adjacent inner dunes (nature reserve 'Noorduinen'), including the excavation of the upper soil of a reclaimed dune valley and sand quarry down to the 16th century dune-polder transition zone level, revealed the presence of interesting species in the seedbank such as *Carex punctata, C. distans, C. pseudocyperus, C. viridula, C. trinervis, C. flacca, Cyperus longus, Juncus subnodulosus, J. acutiflorus, J. conglomeratus, J. compressus, J. gerardii, …*

6. FLUITHOEK (KOKSIJDE)

Sharp dune-polder transition zone, largely within a NATO airfield. No restoration project planned so far.

7. DUINZOOM OOSTDUINKERKE WEST (KOKSIJDE, OOSTDUINKERKE)

Figure 11. A few years after transformation of a garden centre into an extensively grazed grassland and pond (Elia, Oostduinkerke).

Vague dune-polder transition zone (38 ha). One small privately owned parcel ('Elia site', 1 ha) was transformed from a garden centre into extensively grazed inner dune grassland with a large pond in 2006 (*fig K*). A few target species appeared and are still present: *Carex flacca, C. distans, Juncus conglomeratus, Alopecurus aequalis* and *Primula veris*.

8. LABEURHOEK-ZELTE (OOSTDUINKERKE)

Type of transition zone:

Dune-polder transition zone. 159 ha, 8 ha of which under nature management (*fig. 12*).

Abiotic conditions:

- *Soil types: C2 and essentially Da*
- *Hydrology: six piezometers in nature reserve monitored since 2005, without processing of the results up to now.*
- *Land use: agriculture, mainly pastures on dune soils and arable fields in the polder area; small part managed as a nature reserve (hay meadow, non fertilized arable field).*

Historical references:

- *19th century: predominantly used as arable fields, with pastures mostly on isolated low dunes.*

Figure 12. Former arable land turned into meadowland with newly created ponds (Labeurhoek)

- *Very few ancient botanical data known. In the 1970s Carex paniculata and Juncus subnodulosus were found in a ditch (probably influenced by seepage water from the dunes).*

Problems to be solved:

- *Designation as agricultural area on town and country planning maps.*
- *High nutrient charge in the upper ground layer as a result of the actual agricultural use.*
- *Deep agricultural drainage of the neighbouring area.*

Ecological restoration:

- *Project: execution of nature management plan in Labeurhoek, including hay meadow, intensive grazing (horses of shrimp fishermen) and arable land management without use of fertilizers or herbicides for the protection of farmland birds.*
- *This site is one of the largest dune-polder transition zones along the Belgian coast. The acquisition of additional land is needed to be able to fulfil a major ecological restoration plan.*
- *Results: the hay meadow vegetation remains rather species poor, probably due to the lack of a permanent seed bank and Holcus dominance, though target species Eleocharis uniglumis appeared and botanical potential remains high.*

Figure 13. The transformation of planted woodland to species rich grassland in the Doolaeghe (Hannecartbos)

9. HANNECART WOOD, DOOLAEGHE AND SURROUNDINGS (OOSTDUINKERKE)

Type of transition zone:

Complex transition zone in a fossil beach plain landscape. Sandy (partly decalcified), silty and peaty dune transition soils are surrounded by low and high dunes. Unique relicts of 19th century and older semi natural landscape and flora with historical grasslands and remains of arable fields alternating with low hedgehog dunes. Concentration of various ecological transitions with a high biodiversity potential. 60 ha, 42 ha of which under nature management (*fig. 14*).

Abiotic conditions:

- *Soil types: Db, C2-C3 and B1 (dune slacks and hedgehog dunes).*
- *Hydrology: large area with discharge of dune seepage water. The level of the local draining watercourse (Waterloop-Zonder-Naam) is regulated by a series of dams.*
- *Topography: almost flat fossil beach plain surrounded by low dunes to the north and south.*
- *Land use in 2000: planted alder wood (1930-1950), with some relicts of Calthion hay meadow, agricultural pasture and grazed or disused hedgehog dunes, including an artificial lake (former sand quarry).*

Historical references:

- *Pictured as wet or marshy depression on maps from 17th and 18th century; 19th century: mixture of (probably grazed or locally mown) grassland and arable fields, bordered by low dunes.*
- *19th century botanical records: Carex dioica, C. hostiana, Drosera longifolia, Gymnadenia conopsea, Apium repens.*
- *Magnel (1914) describes a 10-15 ha large grassland complex (the Doolaeghe) with an intriguing combination of species of mesotrophic marsh (Menyanthes trifoliata, Ranunculus lingua), peaty meadow (Eriophorum angustifolium, Anagallis tenella, Juncus subnodulosus, Valeriana dioica), mesophilous grassland (Cynosurus cristata, Primula veris, Briza media, Rhinanthus minor), dune slack grassland (Parnassia palustris, Gentianella uliginosa) and slightly decalcified humid grassland (Succisa pratensis, Potentilla erecta, Carex panicea).*
- *Up till the 1990s a few remnants were still present: Molinia caerulea, Valeriana dioica, Thalictrum flavum, Orchis morio. Blysmus compressus and Triglochin palustre were found in a road verge.*
- *In the 1970s Triturus cristatus was also recorded on the site.*

Initial problems to be solved:

- *Afforestation of former beach plain grasslands; loss of historical grazing practices on beach plain and hedgehog dune grassland.*
- *Lowering of the water table in the adjacent dunes; drainage through the dune brook 'Waterloop-Zonder-Naam'.*
- *Direct discharges of polluting effluents into the watercourse of WZN.*
- *Destruction and fragmentation of the local dune landscape as a consequence of urbanization i.e. residential area, recreational resorts and local roads.*

Figure 14. Marshy hay meadow (Juncus subnodulosus-Carex flacca type, with Anagallis tenella, Primula veris and Valeriana dioica), in the second year after grassland restoration in the Doolaeghe (Hannecartbos)

Ecological restoration:

- *Project: execution of nature management plans for Hannecartbos (1999) and IWVA-domain (2003), all part of nature reserve Ter Yde, supported by the LIFE-project 'FEYDRA' (Van Nieuwenhuyse, 2006). Two main areas: Doolaeghe (approx.6 ha) and Noordzeedreef/Peerdevisschersweide (3.7 ha).*
- *Scientific basis: floristic inventory, preliminary seed bank analysis, vegetation description and rough vegetation mapping. Several years of detailed measurements of hydrological conditions; soil mapping in the 6 ha target zone of De Doolaeghe. After the active restoration a monitoring programme was set up to evaluate the results of the restoration project (2006-2008).*
- *Target species – target communities: species mix of dune slack communities (Caricion davallianae), wet and humid grasslands (Calthion/Molinion) and oligo/mesotrophic ponds and ditches (with Chara species). Target habitat in the Peerdevisscherswei is species rich Lolio-Potentillion, with Apium repens and Blysmus compressus. Fauna: Triturus cristatus, Vertigo species.*
- *Restoration tools: Deforestation, sod cutting and reprofiling of brook banks using large machinery (2004-2005, with additional actions up to 2008; fig. 13). Hydrological regulation of the dune brook with dams. In the Peerdevisscherswei overgrazing and trampling by fisherman's horses was replaced by a more adequate grazing regime.*
- *Recurrent nature management: year round grazing of parts of the former beach plain area, the adjacent hedgehog dunes and woodland; annual mowing followed by seasonal grazing in summer-autumn of the greater part of the restored Doolaeghe.*

Results:

Topsoils in De Doolaeghe have become wetter and less eutrophic, mainly as a consequence of sod cutting, at least locally. The first three years were very promising, as a significant number of target species and members of target vegetation units established (360 phanerogams on 6 ha), e.g. *Anagallis tenella, Primula veris, Carex viridula, C. panicea, C. distans, Isolepis setaceus, Juncus subnodulosus, J. acutiflorus*. A lot of target species established which were not detected in the initial seed bank analysis, some of these being completely unexpected e.g. *Calluna vulgaris, Erica tetralix, Ulex europeus, Juncus anceps, Potamogeton coloratus*, whereas expected species (*Hippuris vulgaris*) remained absent. Remarkably, a number of species only known from inland grassland systems (*Scirpus sylvaticus, Achillea ptarmica, Persicaria bistorta*) also established, without any trace of (involuntarily) introduction. However, some other species clearly colonized the site by means of management machinery (*Rhinanthus angustifolius, Pedicularis palustris*). Five years after restoration, anemochorous target species of the *Caricion davallianae*-dune slacks (*Parnassia palustris, Epipactis palustris, Dactylorhiza spp.*) have started building up populations. These early stages of promising vegetation development may however be negatively influenced by the spread of competitive species as *Holcus lanatus, Trifolium repens* and *Ranunculus repens* (*fig. 15*).

Figure 15. Vegetation map (2010) of the Doolaeghe, 5 years after nature restoration was carried out.

The newly installed grazing regime in the Peerdevisscherswei (continuous intensive grazing by horses without fertilizing or heavy trampling) proved very successful and produced one of the richest *Lolio-Potentillion* vegetations in Flanders (*Apium repens, Triglochin palustris, Blysmus compressus, Carex flacca, Trifolium fragiferum, Anagallis tenella*).

Populations of *Vertigo moulinsiana* and other rare *Vertigo* species have consolidated, *Triturus cristatus* has not yet reappeared.

10. SANTHOOFT/LENSPOLDER (NIEUWPOORT)

Figure 16. Intensive agricultural use has a negative effect on the potentially very valuable low dunes and the dune-polder transition zone of Santhooft/Lenspolder.

Complex area within a fossil beach plain in the IJzer estuary that has been reclaimed since 1300. 65 ha, all still in agricultural use. Interesting remnant populations of *Polygalo-Koelerion* species e.g. *Asperula cynanchica, Orobanche caryophyllacea, Potentilla neumanniana, Thesium humifusum, Thymus pulegioides,* *Trifolium scabrum*, which are threatened by a lack of adequate management (*fig. 16*). A plan was drawn up for the afforestation of a large part of the polder area, combined with nature management of the dune and dune-polder transition zones as a grassland area. No achievements yet.

11. GROENENDIJK (NIEUWPOORT)

Type of transition zone:

Part of the same complex area as 9 and 10, with fossil beach plain deposits. 30 ha, 5 ha of which (Groenendijk) under nature management (*fig. 17*).

Figure 17. On the former beach plain of Groenendijk, an abandoned wastewater purification plant was transformed into an area of ponds and grasslands. The whole site is now managed as a hay meadow, with additional grazing during winter.

Abiotic conditions:

- *Soil types: dune (type B1 & B2) and transition soils C2 & Db, (29 ha)*
- *Hydrology: some local hydrological discharge point in the north of this area*
- *Land use: mainly agricultural, with pastures and arable land, and nature reserve (5 ha), with scattered housing and recreational sites.*

Historical reference:

- *19th century: total area used as pasture (especially zone bordering the younger dunes) and arable fields. The area was heavily bombed during WWI.*
- *Ancient botanical sources mention Anacamptis pyramidalis and Apium repens from this area.*

Problems to be solved:

- *Isolation and fragmentation of the area.*
- *Largest part still privately owned.*
- *Deeply founded buildings and concrete constructions in the project area*

Ecological restoration:

- *Project: part of FEYDRA- Life project (former wastewater treatment site, 5 ha), in application of nature management plan (2007)*
- *Scientific basis: initial inventories of flora and fauna, vegetation and some preliminary hydrological measurements.*
- *Target species – target communities: elements of Calthion, Cynosurion, Arrhenaterion, Charetalia, Caricion davallianae and Galio-Koelerion.*
- *Restoration action: demolition of the former wastewater treatment plant, excavation of 4 major dune ponds at this place and creation of an area of dry low dunes.*
- *Recurrent nature management: annual mowing of wet and mesophilic hay meadow (Calthion- Arrhenaterion) and the newly created mesotrophic grasslands (Arrhenaterion -Cynosurion), followed by seasonal grazing by horses or cattle). Initially, algae had to be regularly removed from ponds.*

Results:

Several target species related to different habitats have established: *Characea* and *Ranunculus baudoti* in almost all ponds; pioneer species of wet nutrient-poor alkaline soils *Centaurium pulchellum, Samolus valerandii, Isolepis setaceus, Carex flacca, C. viridula*. The relictual vegetation of the wet and mesophilous hay meadows has extended in area and quality, with e.g. *Juncus subnodulosus, Rhinanthus angustifolius, Bromus racemosus, Dactylorhiza majalis, Scirpus sylvaticus, Primula veris, Orobanche purpurea*. Unfortunately, Habitat Directive annex II-species *Apium repens* and *Anagallis tenella* disappeared soon after their establishment from the seed bank (suffocated by algae).

The annual bloom of algae in almost all ponds is a problem. The worst situation however occurs in the pond situated in the area of the former sludge basins, indicating major influence of remaining nutrients. Ad hoc management involves manual clean-up of the algae in order to prevent the disappearance of target species and the construction of a local dam to prevent hydrological contact with eutrophicated sites.

12. IJZERMONDING (NIEUWPOORT)

Type of transition zone:

Largely artificial dune-salt marsh transition zones transformed out of sandy and silty dredging deposits. Ca 4.75 ha, completely under nature management (*fig. 18*).

Figure 18. Overview of the IJzermonding nature restoration area. Dune-saltmarsh transition zones can be distinguished by the pale colour.

Abiotic conditions:

- *Soil types: calcium-rich beach sands, blond and grey dune sands, intertidal silty and sandy soils.*

Historical reference:

- *The current situation is completely artificial, but a number of very special species are known from its 19th century local equivalents: Carex divisa, Trifolium squamosum, Bupleurum tenuissimum, Oenanthe peucedanifolia, O. lachenalii.*

Initial problems to be solved:

- *The dune-salt marsh transition zone has been cut of from tidal influence since when an artificial bank was constructed for a golf course*
- *In the 1950s the area was partly raised with clayey-sandy dredging sludge from the IJzer channel and a marine harbour with buildings and concrete roads was established on the site. Large parts of the dune area were levelled.*

Ecological restoration:

- *Project: most actions were supported by the EU LIFE-project ICCI (Integrated Coastal Conservation Initiative; 1997-2001), including a scientifically based project report, evaluation and follow-up in a nature reserve management plan (Hoffmann et al. 2005). Based on this management plan, additional actions were executed in 2010 and are under study.*
- *Scientific basis: vegetation mapping, soil analysis, analysis of historical maps and aerial photographs, biological inventories*
- *Target species – target communities: Thero-Salicornion, Puccinellion maritimae, Armerion maritimae (salt marsh); Saginion maritimae and Atriplicion littoralis in the pioneer stages of the transition zone vegetation development. The creation of brackish reedbeds and contact zones with fresh seepage water are under study.*
- *Restoration tools: large scale removal of former dredging sludge dump, reshaping of an intertidal landscape and construction of new embankments.*
- *Actual recurrent nature management: periodical sheep grazing management with fluctuating flock size. Manual removal of anthropogenic litter at the flood mark. Local periodic mowing of rough dune grassland and cutting of scrub.*

Results:
Ecotones characterized by salt-fresh water, silty-sandy, moist-dry and tidal gradients. Saginion maritimae and Atriplicion littoralis communities are found in the transition area of salt and fresh water, (with e.g. Sagina maritima, Parapholis strigosa, Beta vulgaris subsp. maritima, Glaux maritima, Atriplex littoralis, Salsola kali ssp. kali, Cakile maritima) and these pioneer stages are thriving. Later stages and areas higher up the gradient have evolved, after an interesting start (with establishment of e.g. Chenopodium chenopodiodes and Carex distans), rapidly towards species poor dense reedbeds. The artificial creation of a broad and differentiated transition zone of low dunes and sandy depressions proved not very successful due to the erosion of these (non-vegetated) areas. Restoration and management of artificial dune-salt marsh transition zones proved to be more problematic then the adjacent salt marsh and dune grassland.

13. HEMMEPOLDER (NIEUWPOORT-MIDDELKERKE)

Area with a complex history, formerly a part of the eastern branch of the IJzer estuary, with transitions between dunes, former beach plain and polder deposits and with remnant of a tidal creek (17 ha). Current land use is intensive agriculture. A restoration plan is developed but so far no action is undertaken.

14. SCHUDDEBEURZE (WESTENDE-MIDDELKERKE)

Type of transition zone:
The Schuddebeurze dune site is a remnant of a low-lying dune system typical of estuarine systems. It was probably formed in the Early Middle Ages. Centuries of leaching resulted in a largely decalcified soil. The site is essentially surrounded by somewhat lime rich polders, resulting in a specific type of transition zone (*fig. 19*). 193 ha, 34 ha of which under nature management.

Abiotic conditions:

- *Soil types: essentially dune (C2, B1, B2) and transition soils Da & Db*
- *Hydrology: surveyed since 1998. It is probably largely an infiltration zone although there is no knowledge about seepage because of the absence of deep piezometers. The amplitude of phreatic groundwater fluctuations slightly increases towards the polder.*
- *Land use: agriculture, mainly pastures on dune soils and arable fields in the polder area.*

Figure 19. Once a waste dump, now a clear pool inviting Triturus cristatus to breed … (Schuddebeurze).

Historical reference:

- *19th century: a mixture of dune heath, small pastures and arable fields on dune and polder soils. Also a few wooded parcels are depicted.*
- *Old botanical sources mostly regard the dry dune heath part of the site, with Calluna vulgaris, but also Carex trinervis* and *Centunculus minimus. Until the 1970s relict species of wet decalcified dunes and transition zones were still present: Juncus acutiflorus, Nardus stricta, Apium repens, Sphagnum sp.*

Problems to be solved:

- *Designation as agricultural area on the town and country planning maps of part of the site.*
- *Fragmentation (mainly by roads).*
- *High nutrient charge in the upper ground layer as a result of the actual agricultural use*
- *Polder drainage.*
- *Old waste dumps, ruins, war remnants.*

Ecological restoration:

- *Projects: within the legally protected dunes and transition zone, an acquisition and management programme is carried out by the NGO Natuurpunt. ANB created two new pools.*
- *Scientific basis: best professional judgement.*
- *Target species – target communities: until now, restoration actions are mainly targeted at the decalcified dunes (including small remnants of coastal heathland with Ulex europaeus and Calluna vulgaris). Ecological potentials for the transition zone can mainly be expressed in humid grassland, freshwater marsh and open water habitats. One of the important target species still having a small population in the area is the Annex II-species Triturus cristatus.*
- *Restoration tools: restoration of heath and decalcified grassland primarily includes grazing without fertilization to restore heath and decalcified grassland, but also some small-scale excavations of levelled depressions. The sanitation of a former waste dump and the ruins of a small building resulted in two rather large ponds in the dune-polder transition zone, while an existing former sand pit was cleaned.*
- *Recurrent nature management: cattle grazing and local mowing.*

Results:

Heath and grassland restoration already resulted in local establishment of *Calluna vulgaris, Potentilla erecta, Danthonia decumbens, Trifolium subterraneum* etc and a sharp decline in productivity of the managed grasslands. The relictual population of *Triturus cristatus* profited from the new and restored ponds.

15. SCHAPENWEIDE (MIDDELKERKE)

This site is probably the only remnant of a medieval sea defence structure consisting of a double embankment system, in Dutch called an ‘inlaag’. More of these ‘inlagen’ are still found in De Fonteintjes (see site 22). The site itself is only 1.1 ha, consisting of a single pond surrounded by an embankment, but it is part of a larger, also largely artificial, front dune system (see sites 16 & 17).

16. WALRAEVERSIJDE (OOSTENDE)

Figure 20. Dune-polder transition zone of Walraeversijde in winter. After nature restoration, lack of adequate management led to species poor reed beds.

Type of transition zone:

Sharp dune-polder transition area. 20 ha, the whole area being protected and managed as a (partly gone wild) public park (province of West-Vlaanderen, ANB) (*fig. 20*).

Abiotic conditions:

- *Soil types: some C2 (levelled dune soils) but mainly Da dune-polder transition soils*
- *Hydrology: discharge of dune groundwater occurred very locally, near basis of dunes.*
- *Topography: flat*
- *Former land use: gardens and pasture (dune transition zone) and arable fields (polder part)*

Historical reference:

- *19th century: a mixture of agricultural grasslands, arable fields and gardens.*
- *No old botanical data are known.*
- *Archaeological remains of the medieval village of Walraeversyde indicate that Cladium mariscus was used for thatching. So mesotrophic marshes most probably existed in the area.*

Problems to be solved:

- *Polder drainage effects*
- *High nutrient charge in upper ground layer*
- *Lack of adequate nature management*

Ecological restoration:

- *Project: 3 ha of former agricultural land in the dune-polder transition zone of the Provincial Park were turned into marshland and meadows in 1998, together with 1.5 ha of polder soils, A 4.5 ha transition zone was transformed in 2008.*
- *Scientific basis: floristic inventory, vegetation description and rough mapping. One year of hydrological measurements + soil mapping of the original 2 ha target zone (using a 25x25m grid, including humus layer, texture & depth of water logged soil layer). A new management plan is under study.*
- *Target species – target communities: species mix of dune slack communities (Caricion davallianae), wet polder grasslands (mainly Cynosurion & Lolio-Potentillion elements) and mesotrophic ponds.*
- *Restoration tools: removal of the organic soil horizon and leaving the mineral C-horizon intact (sod cutting) using large machinery. Attempt to reduce the effects of polder drainage by hydrological isolation of a local ditch. No target species were introduced. The second phase of the nature restoration project included the excavation of a large shallow pond and the reprofiling of the banks of a polder drainage channel.*
- *Recurrent nature management: mowing twice a year (July & September), often failing however, due to hydrological conditions of the site.*

Results:

In the original nature restoration zone, topsoils locally have become wetter, mainly as a consequence of sod cutting. The first years were very promising, as a significant number of target species and members of target vegetation units established e.g. *Apium graveolens, Aster tripolium, Carex distans, Carex flacca, Carex viridula, Glaux maritima, Isolepis setaceus, Juncus gerardii, Samolus valerandi, Trichlogin palustris*. By 2009 almost no target species remained, except for *Carex flacca* and *Samolus valerandi*. In the polder, *Butomus umbellatus* and *Trifolium fragiferum* were recorded and remained. After 10 years the most promising areas evolved into a reed marsh. At least partially this was due to inadequate nature management i.e. interruption of the initial mowing regime, mainly because of practical problems (soils were too wet for mowing with large machinery). Perhaps some species did not establish because nearby source populations were not present and seedbank species may have disappeared because growing conditions did not match their ecological needs. Ponds now need to be cleaned up in order to give more space to typical water vegetation (*Chara spp, Myriophyllum spp. and Ranunculus sect. Batrachium*). In the 2008 project area, newly established target species include *Callitriche truncata, Centaurium pulchellum, Apium graveolens, Juncus subnodulosus, Juncus compressus, Ophrys apifera;* again a promising starting point, if adequate follow up can be guaranteed. The dune-polder transition zone in the part of the park site managed by ANB, which has a rather wild character (abandoned garden, reedbeds, wet willow marsh), may also have potential for nature restoration.

17. MARIAKERKE (OOSTENDE)

Sharp dune-polder transition; one of the smallest coastal sites in Belgium. Probably the dune was formed by sand accumulation seaward of a sea defence embankment, giving the entire area a largely artificial geomorphology. 6ha, no current nature management, but a nature development project is being studied (City of Oostende).

18. D'HEYE (BREDENE-DE HAAN)

Type of transition zone:
D'Heye is a low dune system that was probably formed, very similar to the already mentioned Schuddebeurze (nr 14), in a former 'estuarine' environment, specifically around the mouth of a tidal channel. The age is still subject to debate but the deeply decalcified soils suggest a somewhat similar age to the Schuddebeurze area. 30 ha, 15 ha of which is under nature management.

Figure 21. Periodically inundated grazed marsh area, created through excavation of formerly heavily fertilized agricultural grassland in D'Heye. However promising abiotic variety and initial botanical results may be, nature restoration projects in urbanized areas always risk disturbance by invasive alien species (e.g. Crassula helmsii).

Abiotic conditions:
- *Soil types: the site currently consists of a decalcified dune area, mainly C1 (levelled dune soils) surrounded by Da & Db dune-polder transition soils and lime rich polder soils.*
- *Hydrology: network of piezometers since 2001. Partly rather large groundwater fluctuations. However, the lack of deep piezometers does not enable us to model groundwater flow and determine seepage processes. Part of the area was used for water extraction until 2008. The former extraction area now being part of the nature reserve, recovery of a more natural hydrology is expected.*
- *Topography: largely levelled or low dunes*
- *Land use: agricultural use (pastures) and drink water production, recently mostly changed to grazing and locally mowing without use of fertilizers (nature reserve).*

Historical reference:
19th century: most of the low dunes area used as grassland (probably pasture, in fact at least partially heathland), with arable land in dune-polder transition zone. 19th and early 20th century botanical sources mention a.o. *Cicendia filiformis, Eriophorum angustifolium, Spiranthes spiralis, Centunculus minimus* and *Hypochaeris glabra* from the site.

Ecological restoration:
- *Project: execution of nature reserve management plan (2000).*
- *Scientific basis: floristic inventory, vegetation description and vegetation mapping. Hydrological monitoring of 17+8 piezometers since 2001/2007.*
- *Target species – target communities: mainly dry Festuco-Galietum dune grasslands, dune heath and humid to wet Cynosurion, Lolio-Potentillion and Arrhenatherion grasslands of the dune-polder transition zone. A well established vegetation type in the dry to humid mesotrophic transition zone is 'Trifolium-rich grassland', characterized by a large number of Trifolium species such as T. subterraneum, T. striatum, T. micranthum, T. scabrum, T. arvense and several more common species. Locally these grasslands can be very rich in rare grassland fungi (e.g. Hygrocybe). A second focus is on wet habitats such as marshes and ponds.*
- *Restoration tools: 2-3 ha have been reprofiled and some ponds were restored or newly created.*
- *Recurrent nature management: Rather intensive permanent grazing (horses, sheep, cattle) without fertilizing in order to maintain a short turf over large parts of the site. Local mowing of hay meadows, followed by grazing in winter, and arable farming without using pesticides.*

Results: Until present only a limited number of new target plant species have appeared, but the species already present have maintained their position or have even expanded their population: *Orobanche purpurea*, *Danthonia decumbens*, *Calluna vulgaris*, *Ulex europaeus*. A small cornfield created in the transition zone and managed for arable field birds also yields some interesting arable weeds: *Kickxia elatine*, *Anthemis cotula*, *Stachys arvensis*. A problem on this site is the invasion of several alien species of which *Crassula helmsii* is the most problematic (*fig. 21*). Unfortunately the presence of *Triturus cristatus* remains limited to an adjacent private garden pond.

19-20. INLAND DUNES OF VOSSESLAG & VLISSEGEM (DE HAAN)

The origin of the sandy area and dune-polder transition zone around Vlissegem is unclear but these dunes are probably remnants of sand flats and low dunes associated with former tidal channels (cf. D'Heye 18). Completely in agricultural use, often used for horse breeding or riding stables. About 170 ha, none under nature management.

21. DUNE RIDGE DE HAAN

Small dune area with a very sharp transition into the polders; 13 ha, none under nature management.

22. FONTEINTJES (BLANKENBERGE)

Type of transition zone:

The dune system between Blankenberge and Zeebrugge is largely man made. Much like the Schapenweide (see 15) it originally was a coastal defence structure consisting of a double embankment ('inlaag'; *fig. 22*). A dune ridge was formed through sand accumulation seaward of the embankments. It can now be considered as a small dune area with a very sharp transition to the polders, but the depression between the ancient banks itself forms a diversified dune-polder transition zone. 21 ha, 9.6 ha of which under nature management.

Abiotic conditions:

- *Soil types: high dunes (A0) – 12 ha, and small areas of highly disturbed soils at the base of these dunes.*
- *Hydrology: due to the vicinity of the sea, groundwater fluctuations are limited to about 40cm on an annual basis.*
- *Land use: coastal defence, nature reserve and recreational use.*

Figure 22. The 'inlagen' coast between Blankenberge and Heist on the de Ferraris map (c. 1770), with grasslands, marshes and ponds behind a very narrow dune ridge.

Historical reference:

- *The area has probably been characterized by marshes and wet grasslands since medieval times, with little arable land. Most of the original transition area has disappeared under industrial urban and recreational development since the end of the 19th century.*
- *In the 19th century, the 'inlagen' area of Blankenberge-Heist was one of the most renown botanical sites along the Belgian coast, harbouring a rich fen flora with species such as Liparis loeselii, Orchis palustris, Pedicularis palustris, Cladium mariscus, Potamogeton coloratus, P. friesii and Utricularia vulgaris alongside more traditional dune slack flora (Parnassia palustris). While species composition is somewhat different, the presence of rich fen species, species richness and habitat diversity are clearly reminiscent of the historical flora of Hannecart wood and surroundings (zone 9). In addition to some abiotic conditions, both sites are characterized by their long history of more or less continuous grassland and marsh habitat.*

Ecological restoration:

- *Project: no specific restoration project, but part of the remaining site has been managed as a nature reserve since the end of the 1960s, starting from an undermanaged marsh and fishpond area.*
- *Target species – target habitats: conservation of the remaining relicts of the dune slack flora and habitats (with e.g. Dactylorhiza praetermissa, Ophioglossum vulgatum, Hippuris vulgaris, Potamogeton coloratus)*
- *Nature restoration tools: the current conservation value of the site is largely related to continuous management as a hay meadow by the NGO Natuurpunt.*
- *Recurrent nature management: annual mowing of the wet slacks and periodical scrub clearing.*

Results:

40 years of nature management have resulted in the conservation of a botanically rich area with all the remaining botanical target species, all be it sometimes in small and temporal populations. New target species such as *Epipactis palustris*, *Ophrys apifera* and *Juncus subnodulosus* (a competitive species so also a possible threat to other target species) have established. The 19th century rich fen flora could not been restored, however. Periodical inundation in late spring and early summer continues to demand attention.

23. BAAI VAN HEIST (KNOKKE-HEIST)

Type of transition zone:

The green beach in Heist is one of the most interesting transition zones along the Belgian coast. The site is associated with the development of the port of Zeebrugge. The construction of the large eastern pier of the harbour in particular gave rise to a sedimentary environment on its NE side. The nature reserve area is currently 36 ha, but the sedimentation processes are still ongoing. The site is still evolving with the formation of new embryonic dunes, sedimentation and erosion. There are several transition areas within the nature reserve, some only temporarily. Probably the most characteristic is now the broad transition zone between low grey dunes and salt marsh (*fig. 23*). A thick shell layer has been deposited in places, creating major potential breeding opportunities for rare birds such as *Sterna albifrons* or *Charadrius alexandrinus*, both of which are included in annex I of the EU Birds Directive.

Abiotic conditions:

- *Soil types: aeolian and marine (silty) sand deposits, with local dominance of shells.*
- *Hydrology: mainly salt conditions as a consequence of frequent marine inundation. At the basis of the low dunes (limited) fresh water seepage occurs giving rise to characteristic vegetation communities (Saginion maritimae).*
- *Land use: nature reserve since 1997*

Figure 23. The 'green beach' of the Baai van Heist, with stabilizing embryonic dunes (evolving into grey dunes), brackish reed marsh an salt marsh pioneer vegetation.

Historical reference:

Not relevant as the area as a whole has only existed since the 1980s.

Problems to be solved:

- *Initially the area was used for beach recreation, including recreational fishing. Local acceptance of the site as a nature reserve with restricted access took some time.*
- *Dominance of Elymus athericus in the transition zone between low dunes and salt marsh*
- *Colonization by alien plant species (Melilotus albus, ...)*

Ecological management:

- *Project: execution of nature reserve management plan (2000).*
- *Scientific basis: floristic and faunal (birds) inventory, vegetation description and periodical vegetation mapping.*
- *Target species – target communities: embryonic dunes and floodmark vegetation, dry Tortulo-Koelerion grey dunes, salt marsh vegetation and transitional communities (e.g. Saginion maritimae). Breeding seeside birds: Sterna albifrons, Charadrius alexandrinus, Charadrius hiaticula, Galerida cristata.*
- *Recurrent nature management: mowing of Elymus athericus every two years and manual removal of alien plant species such as Melilotus albus, Baccharis halimifolia.*

Results:

Botanically, the site is now of regional importance for species such as *Puccinellia fasciculata, Parapholis strigosa, Catapodium marinum, Honckenya peploides* and *Aster tripolium*. The rare moss *Henediella heimii* is also found on the site. Disruptive recreation is no longer allowed, but the nature reserve is open to visitors who use the signed footpaths and observation points. As a consequence, vegetation development occurs almost naturally and some characteristic birds (e.g. *Sterna albifrons, Charadrius alexandrinus, Charadrius hiaticula, Galerida cristata*) have opportunities to breed.

24. OUDE HAZEGRASPOLDER (KNOKKE-HEIST)

Gradual dune-polder transition area with some characteristic remnants of the former, small-scale agricultural landscape (small fields and pastures surrounded by trees or hedges and with some ponds. Also some small wooded parcels are remnants of the late 18th-19th century agricultural landscape. 161 ha, none of which is under nature management, although a network of pools (Hyla-project) was created on private lands.

25. ZWINDUINEN (KNOKKE-HEIST)

Type of transition zone:

The 'Zwinduinen en–polders' site consists of a former beach plain/salt marsh area behind a broad zone of rather low and topographically divers frontal dune, reclaimed in 1872 from the tidal area of the Zwin. The nature reserve is 220 ha, 170 ha of which can be considered to be a transitory environment (Zwaenepoel et al. 2007). Another 18 ha is managed as a provincial park. Although once used as a golf course, the topography of the western part of the site (Groenpleinduinen and 'Far West') is still intact, partly with semi-natural vegetation of grasslands, thickets, tall herbs, reedbeds and local plantations. The typical topography of the tidal flat and low dunes of the eastern part (Kleyne Vlakte, Tobruk) is due to leveling for the construction of an airport (±1930) with accompanying airstrips and drainage systems. It was partially used as agricultural pasture, partially planted with woodland. The area is drained by a temporarily dry and partly artificial dune brook (Paardemarktbeek) and an extensive underground drainage system.

Figure 24. Western part of 'De Zwinduinen en -polders' ('Far West') after nature restoration (scrub removal, sod cutting and reprofiling of the Paardemarktbeek).

Abiotic conditions:

- *Soil types: northern and western parts: mainly dune sands, southern and eastern part essentially sandy soils with silty layers or polder clay covering maritime sands.*
- *Hydrology: Partly dune groundwater system (infiltration zone without superficial drainage), partly typical dune-polder transition hydrology, with local discharge of local dune or deep (brackish) seepage water and superficial drainage by a brook and ditches. The hydrology of the eastern part in particular is strongly influenced by internal underground drainage systems and by the deep drainage of the adjacent agricultural polder area.*
- *Topography: Essentially an almost flat area with some remnants of a former creek and salt marsh depressions, to the north and west surrounded by low dunes. Topography of the eastern half of the site has been artificially levelled.*
- *Land use up to 2000: the southern and eastern parts of the site were essentially seasonally grazed pastures (cattle), often fertilized and treated with herbicides. There is also a small area formerly used as a carting circuit, which was already excavated at the beginning of the years 2000, as a first measure of nature restoration.*

Historical references:

- *Most 19th century botanical data of the salt marsh and transitional flora of 'la pointe de Knocke' probably refer to this area.*
- *Only in the second half of the 20th century (especially the 1970s) did we develop more detailed knowledge of the current Zwinduinen site: that includes (not always well documented) records of species such as Orchis morio, Briza media, Gentianella uliginosa, Schoenus nigricans, Juncus maritimus, Ophioglossum vulgatum and Botrychium lunaria as well as rare fungi (Hygrocybe) .*
- *Among ornithologists the site is best known for its breeding birds: Egretta garzetta, Ardea cinerea, Platalea leucorodia.*
- *In recent decades breeding populations of Hyla arborea, Epidalea calamita and Triturus cristatus have been observed.*

Problems to be solved:

- *Historical levelling of the former airport site (Kleyne Vlakte & Tobruk)*
- *Polder drainage and internal artificial drainage system*
- *Negative effects of former agricultural use (fertilization, use of herbicides)*
- *Woodland plantations (only a problem locally)*
- *Lack of management (mowing, grazing) in western part of the site: scrub encroachment, dominance of competitive grasses and herbs*

Ecological restoration:

- *Project: LIFE nature project ZENO, in application of the nature management plan (Zwaenepoel et al. 2007)*
- *Scientific basis: floristic inventory, vegetation description & rough mapping, soil mapping of the target zone. Detailed modelling of hydrological conditions was based on data of a piezometer network (approx. 40 piezometers) covering the whole restoration site, starting in 2003. The modelling entailed a prediction of hydrological conditions after the planned actions.*
- *Target species – target communities: in the western parts of the dune-polder transition zone in particular, emphasis is on the restoration of vegetation types of moderately lime-rich to slightly decalcified (primary) dune slacks (Caricion davallianae, Lolio-Potentillion, Rhinantho-Orchietum morionis, Botrychio-Polygaletum) and dry dune grasslands (Festuco-Galietum) and accompanying species (Gentianella uliginosa, Carex viridula, Rhinanthus minor, Trifolium species, Potentilla argentea). Target grassland communities in the often more clayey eastern part of the site comprise Cynosurion and Lolio-Potentillion communities. A wide variety of vegetations from (oligo- to eutrophic, permanent to temporary) ponds and other water bodies with Charetalia, Lemnetalia & Potametalia, with Lolio-Potentillion, Phragmitetalia & Nasturtio-Glycerietalia bank vegetations form another target habitat for the whole of the area. Large water bodies and inundated grasslands are expected to result in higher numbers of target birds (waders, meadow birds) and isolated ponds are expected to revive the relict populations of at least Triturus cristatus and Hyla arborea.*
- *Restoration tools: in the first years before the ZENO project and the implementation of the nature management plan, only small-scale preservation actions were carried out (mowing or grazing some remaining dune grasslands). Large-scale ZENO actions in afforested and scrub-dominated parts of the site initially comprised the removal of (planted) trees and scrub and the shallow excavation of humic topsoil (2007-2009), accompanied by the cleaning and profiling of existing ponds and the dune brook. The Paardemarktbeek is blocked by a series of controllable dams to stop the rapid discharge of freshwater towards the deep drainage system of the adjacent polders and the water is redirected towards a large excavated depression in the centre of the area (fig. 25). In the central and eastern parts of the site (Kleyne Vlakte) the (artificially levelled) topography has been changed more drastically by local excavation of differentiated ponds, creeks and shallow depressions and the re-creation of low dunes and heights (2009-2010). Plans for the resalinization of the outermost*

south-eastern depression are on hold.

- *Recurrent nature management: a variety of management schemes is planned for the site. In the most westerly parts the grassland area is managed by yearly mowing, the northern 'Far West' is permanently but extensively grazed by cattle, while the southern half of this part of the reserve is a hay meadow with additional grazing in autumn and winter, In the Kleyne Vlakte and adjacent non wooded parts of Tobruk a scheme of year-round grazing by cattle, horses and sheep, supported by mowing when and where necessary (Cirsium arvense), started in 2010.*

Figure 25. A shallow depression was excavated in the central part of the area in order to create an infiltration basin for the water of the Paardemarktbeek.

Results:

As the main restoration actions will not be finished before the end of 2010, results are still very provisional. The scientific monitoring of the nature restoration is scheduled in the next few years. The results of local relict management (small-scale mowing) proved to be positive (increase of target species such as *Gentianella, Danthonia, Ophioglossum*). Formerly fertilized hay meadows have already regained colour locally (*Rhinanthus minor, Lathyrus pratensis, Orobanche purpurea, Oenanthe lachenalii*) and in a few pastures such species as *Trifolium striatum, Potentilla argentea* and *Thymus pulegioides* thrive. On the shallowly excavated sites and the profiled banks of ponds of the 2007-2008 restoration actions, very promising pioneer vegetations with *Juncus anceps, Centaurium littorale, Carex distans, Sagina nodosa*, etc have developed. The relict population

of *Triturus cristatus* has increased and the first singing *Hyla arborea* in decades has been heard in one of the restored pools. Hydrological models forecast an increase in the mean groundwater level by 50-10 cm within approx. 250 m of the infiltration basin. However, the winter of 2009-2010 made already clear that the damming of the brook may inundate larger parts of the site to a higher level than was first expected. In spring and early summer this may create problems for target habitats such as *Caricion davallianae, Rhinantho-Orchietum morionis* and *Botrychio-Polygaletum*. The discovery and subsequent destruction of the

Figure 26. The transition zone between rarely inundated low dune and salt marsh is often formed by a narrow fringe of Juncus maritimus and J. gerardii. In Het Zwin this zone is locally accentuated by seepage of fresh water and the presence of Carex extensa.

drainage pipe network (unknown at the moment of modelling) creates further uncertainty. So, the hydrological regulation system may have to be adapted to options for fast, optimal regulation of the various parts of the site and careful follow-up of the installations will be necessary.

26. ZWIN (KNOKKE-HEIST)

Type of transition zone:

Mostly narrow dune-salt marsh transition, including (low) dunes; 56 ha.

Abiotic conditions:
Soil types: calcium-rich dune sands and intertidal silty and sandy soils.

Historical reference:

- *19th century maps: partly non vegetated beach plain; salt marsh and low dunes used as pasture (sheep).*
- *Old botanical sources are difficult to locate: in the former Zwin estuary species of transitory habitats as Juncus maritimus, Oenanthe lachenalii, Carex extensa, Bupleurum tenuissimum, etc were certainly present.*
- *During WWII and the second half of the 20th century part of the transitory zones were excavated or otherwise destroyed, but species such as Ruppia maritima, Catapodium marinum and Carex extensa were certainly present until the 1980s.*

Problems to be solved:
Due to lack of management, the entire salt marsh system, including dunes and transition zones became dominated by coarse grasses, mainly *Elymus athericus*.

Ecological restoration:

- *Project: the entire Zwin area will be subject to drastic changes if the salt marsh restoration planned in the approved Life project ZTAR is carried out (2011-2015).*
- *Scientific basis: a new floristic and faunal inventory, vegetation description and vegetation mapping have been started.*
- *Target species – target communities: to be determined, but no doubt optimizing transitory vegetations (Saginion maritimae, Juncus maritimus fringes, Lolio-Potentillion with Oenanthe lachenalii) and the restoration of (slightly) brackish pools (Ruppia maritima, Epidalea calamita) will be provided for.*
- *Restoration tools: grazing, restoration or creation of (brackish) pools.*
- *Recurrent nature management: part of the salt marsh, including parts of the dune-salt marsh transition zone, has been grazed experimentally by cattle since 2008. The grazed area will probably be expanded.*

Results:
First results of the experimental grazing are very positive as the dominance of grasses has diminished and a new population of *Carex extensa* was discovered in the grazed (and trampled) *Juncus maritimus* fringe.

V PRELIMINARY FAUNAL COMMENTS

Between 2007 and 2010, an intensive biotic inventory was carried out in a selection of dunes managed by the Flemish Agency for Nature and Forests. Largely based on these censuses, we can derive some preliminary results and conclusions.

Birds:
The surveyed dune-polder transition zones (areas 1, 3, 4, 5, 8, 9, 11, 18, 25) contain several species typically associated with marshland and reedbed habitats. Some very common birds such as *Gallinula chloropus, Fulica atra, Acrocephalus schoenobaenus, Acrocephalus scirpaceus, Acrocephalus palustris* were present at almost every site, But some less common species were also recorded at some sites, such as *Luscinia svecica (EU-Annex-I), Emberiza schoeniclus* and *Locustella naevia*.

Some birds are typical of semi-open landscapes with scattered bushes, e.g. *Sylvia communis*, whereas others are more related to the arable fields and pastures of the open polder landscape, e.g. *Perdix perdix, Alauda arvensis* and *Anthus pratensis* (rarely recorded).

Some forested sites are the breeding site for a colony of *Ardea cinerea* (Hannecart) and *Egretta garzetta* (Zwinduinen).

The current breeding bird community of the dune-salt marsh or dune-beach transition areas contains some specific bird species such as *Recurvirostra avosetta* (IJzermonding) or *Sterna albifrons, Charadrius alexandrinus, Charadrius hiaticula, Galerida cristata* (Baai van Heist), all of which can be considered as target species for this habitat.

Amphibians:
Some rare amphibians are target species for dune and dune-polder transition habitats. The annex II *Triturus cristatus* (*fig. 27*) is currently only found in Cabour, Zwartenhoek, Oosthoek, Schuddebeurze and Zwinduinen. This newt is probably also still present in D'Heye, but it was only recorded in a private pond outside the nature reserve.

The annex IV *Epidalea calamita* was only recorded in one dune polder transition area (Oosthoek) and in the polder area near Zwartenhoek. For both species the dune-polder transition zones are - at least potentially - very important as a corridor between remaining dune areas. New ponds, even on farmland, can provide a suitable habitat for amphibians, but to benefit newts, they should not be stocked with fish or subject to heavy waterfowl use.

The annex IV *Hyla arborea* has almost disappeared from the Belgian dune area. A specific action plan has been set up for the population near the Zwinduinen.

Figure 27. Triturus cristatus

Butterflies:
A general decline is observed for almost all species throughout Flanders. However most common species and some specific (target) butterfly species survive in several dune areas e.g. *Hipparchia semele* and *Issoria lathonia*. Some former common butterfly species now still have a considerable population in some dune areas e.g. *Lasiommata megera, Pyronia tithonus, Aphantopus hyperanthus*. However, target species are rarely recorded in dune transition zones.

Grasshoppers:
Some rare species in Flanders can be considered as target species for the dune area. *Tetrix ceperoi* is a characteristic pioneer species that is often found after nature restoration works took place.

Along the coast, *Metrioptera roeselii* is associated more with polders than dunes. It could be considered a target species for inner dune ridge zones. One species *Chrysochraon dispar* is only found in D'Heye (along the coast).

Dragonflies:
In general, there are few interesting dragonfly species recorded in the Belgian dunes. Until now the most interesting species from a nature conservation point of view has been *Coenagrion pulchellum*, which is only recorded from Hannecart (very small population). It is a species of peaty marshes and fens, so it may be considered as a target species for dune transition zones with peaty soils. Populations of *Sympecma fusca* and *Ischnura pumilio* can be considered important on a regional scale. Furthermore, the coast acts as a migratory route for many southern species (e.g. *Sympetrum meridionale, Orthetrum brunneum, Aeshna affinis*). Creation of permanent ponds with protection from severe winds is an important restoration target for dragonflies and many other organisms. The inner dune ridge is often a suitable area for pond creation because of its hydrological conditions.

Mammals:
No specific monitoring has been set up. A target species for the semi-natural, small-scale dune-polder transition landscape is *Eliomys quercinus*. This mouse used to have a wider distribution along the inner dune ridge of the Belgian coast than is now the case.

VI CONCLUSIONS

Three main transition types are present along the Belgian coast: **1)** between coastal dunes and polder **2)** between dunes and active salt marsh and **3)** between dunes and (former) estuaries or beach plains. Dune transition soils account for a significant part (500 ha) of the currently unurbanized coastal dune area (3000 ha). In general, dune transition zones are at least potentially important areas for nature conservation because of their specific abiotic conditions. Furthermore, these zones often play an important role in the ecological connectivity of the remaining isolated dunes.

Figure 28. Colourful and very species rich vegetation of the Doolaeghe (Hannecartbos) in the second year after transformation of planted woodland into hay meadow.

So far, large or small nature restoration projects have been carried out in 16 transition zones. Based on the results, several general comments and recommendations can be formulated. Most of the results should be considered preliminary, as all the projects have been carried out in the last decade. Often there is no guarantee of the sustainability of the established species, posing major challenges for future recurrent management.

In general, the results of the restoration vary significantly. No projects can really be considered unsuccessful because in general the initial conditions were far less favourable to biodiversity conservation. The most promising areas and projects so far are Hannecart (Doolaeghe), IJzermonding (dune-active salt marsh transition), Baai van Heist (a still "naturally" expanding area with good potential for sustainable target communities) and the Zwinduinen (large project area).

Before any action is undertaken, good preparation is required. This should at least include detailed information on soil, hydrology and topography, because soil moisture and nutrient content are generally very important to the achievement of good restoration results. Successful restoration of wet habitats will only be possible if hydrological systems are intact or not irreversibly disrupted. In dune polder transition zones, however, hydrological regimes are mostly artificial due to polder water management. Under natural conditions, most dune transition zones would be hydrologically influenced by the sea, which has a stabilizing effect on groundwater fluctuations (*fig. 28*). Hydrological restoration often entails a fundamental change in the polder drainage system, which will most probably have broad public implications and will in any event require the further acquisition of land.

Grootjans et al. (1998) suggest that at least three different abiotic conditions influence restoration potential in wet environments. Restoration conditions are favourable when the soil is nutrient-poor and well buffered, and when the soil remains moist during dry summers. The latter condition is usually only fulfilled when seepage continues to occur. As a consequence, the potentially most promising areas here adjoin large dune areas, as is the case in Hannecartbos. Under such conditions the accumulation of organic matter is slow (Grootjans et al. 1998). Nutrient-poor conditions and flooding in spring prevent the establishment of very productive (and competitive) species, while base-rich conditions stimulate mineralization of organic matter, keeping nutrient stocks low. If the availability of nutrients remains high after restoration, fast-growing species such as *Holcus lanatus, Ranunculus repens* or *Phragmites australis* can establish almost immediately and effectively store nutrients in living and dead material. These competitive species tend to dominate and can easily outcompete the often vulnerable target species.

Target species rapidly established after restoration at several sites. Sometimes these were species not historically found at the sites. Often there is a clear relation to their presence in the soil seed bank. The Doolaeghe project is a very good and intriguing example, where a lot of unexpected species of conservation interest established. However, we must be aware of the possibility of only temporary success, followed by a rapid decrease in target species or communities. This can occur if soil conditions and hydrological regimes are suboptimal or there is a lack of appropriate nature management.

Preliminary soil seed bank analysis only provides a very rough estimate of botanical potentials. In our experience, many species germinating from the seed bank only occur in very small numbers and the probability of them being detected in soil samples in negligible.

Furthermore, not all (target) plant species can rely on a seed bank. Their establishment therefore requires dispersal events from nearby populations, so the connectivity of the remaining dune sites and their transition zones is important. Where a spatial connection is impossible to achieve, other means of diaspore exchange can be considered, e.g. hay transfer or exchange of livestock and management machinery. So far, little attention has been paid to these possibilities.

VII MONITORING

Further surveillance of the restoration results is an essential step in the evaluation. As stressed above, hydrology is often a key factor in restoration success. At most sites, with (potentials for) development of wet habitats, a piezometer network has already been installed, at other sites such networks are planned. Between 2007 and 2010, an intensive biotic inventory was carried out in the dunes managed by the Agency for Nature and Forests (ANB). Flora and vegetation are followed up using permanent plots and GPS mapping of target species. A new typology for vegetation mapping was developed and was used to map several sites . Fauna is surveyed by a number of techniques, mostly based on fixed routes. Inventory of ponds has received special attention. In each pond, vegetation, amphibians and dragonflies have been inventoried.

An issue requiring further attention is the evolution of nutrient availability at the restoration sites and means to control nutrient availability by adequate management.

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3

Ecology and management of the inner dunes in the Southwest Netherlands

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I SUMMARY

The coastal area of the Southwest Netherlands is characterized by broad inner dune areas. These inner dunes originated as beach plains and salt marshes in the Early Middle Ages. In more recent centuries most inland salt marshes were embanked, so the inner dunes are now isolated from the present-day salt marshes and the sea. The inner dunes have altitudes of 3-8 meters above the mean sea level and in many places they are situated on a layer of clay and peat.
The inner dunes form a varied landscape with several endangered habitats and are home to a large number of Red List species. These are mainly habitats for pioneer communities (open water, dune slacks and pioneer communities of the xerosere and dune grasslands) The woodlands in the inner dunes are all of anthropogenic origin and were planted from the Late Middle Ages onwards. They are of minor importance to the conservation of biodiversity, but have great value from a historical point of view as well as for landscape and recreation.

The goal of habitat management in the inner dunes is the conservation of endangered habitats and species. Conservation and restoration of mechanisms that buffer pH in the top soil are most important. This can be achieved by hydrological and geomorphologic methods, such as enabling winter inundations with groundwater rich in Ca++, sod cutting, and restoration of blowouts. Grazing and mowing are important tools to maintain an open vegetation structure and to prevent (renewed) accumulation of freshly produced organic material.

II INTRODUCTION

The coastal area of the Netherlands can be divided into three zones: (1) the estuarine coast of the Southwest Netherlands, (2) the continuous dune coast of the Holland mainland and (3) the barrier islands of the Wadden Sea. This third zone is part of the much larger Wadden Sea area, which extends into Germany and Denmark. On its landward side each of these three types of coasts has its own specific transition zones to inner dunes and salt marshes.
The Wadden Islands have been dynamic units since the Early Holocene. They have a characteristic structure consisting of various components that appear in a certain order from west to east: island head, dune complex, washover complex and island tail (Löffler et al. 2008). Especially the eastern parts have extensive dune-salt marsh transitions. Natural processes, such as sedimentation and erosion, overwash, groundwater flow and vegetation succession, play an important role here.

Dune-salt marsh transitions are absent along the mainland coast of Holland. The present dunes have formed since 900 AD ('Younger Dunes'; Zagwijn, 1984, 1997). They are situated on top of an older system of beach barriers ('Older Dunes'), which forms the basis of the inner dune landscape. This inner dune landscape has been greatly influenced and shaped by humans since the 16th century. They have been the site of sand digging, the construction of stately homes and gardens, horticulture and urban development; Van Dam, 2010).

Originally, there were also beach barriers in the Southwest Netherlands, but they eroded in post-Roman Times, when the present estuaries were formed. The currents and tidal volume of these estuaries have dominated coastal development in this area since then. The dunes of the Southwest Netherlands are characterized by the presence of vast inner dunes, which date back to the Early Middle Ages, when they were connected to beach plains and salt marshes. Almost all inland salt marshes have been diked since the Middle Ages. As a result, the inner dunes were closed off from the tides and the sea centuries ago. New beach plains and salt marshes were formed more recently elsewhere in this coastal landscape. In most cases they are not connected to the existing inner dunes.

III GEOGRAPHICAL POSITON

The coastal area of the Southwest Netherlands lies on the eastern shore of the Southern Belt in the North Sea. It is situated on a clear geological and hydrological gradient. Near the Belgian border the bottom of the Pleistocene sediments is at a depth of 20-30m. Near Hoek van Holland, approx. 60km to the north, it has a depth of approx.300m. The tidal amplitude varies from 3.80m near Vlissingen (Walcheren) to approx.1.65m near Hoek van Holland.

Three major West-European rivers, Rhine, Meuse and Scheldt, flow into the sea in the Southwest Netherlands, creating large estuaries and sea inlets. The main dune areas here are situated on Walcheren, Schouwen, Goeree and Voorne (figure 1). These islands and former islands are separated by sea inlets and estuaries. As part of the Delta Works the Haringvliet and Grevelingen were almost totally closed off from the North Sea. A storm surge barrier has been built in the Oosterschelde. At present the tides have free access only in the Westerschelde estuary, which is the entrance to Antwerp harbour (Belgium).

Figure 1

IV ABIOTIC ENVIRONMENT

The dunes of the Southwest Netherlands are part of the Rhenodunal floral district, which is considered to have a carboniferous sandy soil. However, due to the geological and hydrological gradient (see above) there is considerable abiotic variation in the dune sands of the Southwest Netherlands (see Table I; Van Haperen, 2009). As a result of their long history, the top soil layer of the inner dune areas has been superficially decalcified. In areas with a low initial carbonate content (Walcheren, Schouwen, parts of Goeree) decalcification has advanced down to the lowest groundwater level. The higher parts often have acidic topsoil (pH < 4). In areas that initially had a higher carbonate content (Voorne, also locally on Goeree) decalcification has advanced no more than 0.5-1.0m. Bioturbation by animals (rabbits, moles, mice, ants) and local blowouts introduce free carbonate into the topsoil. The higher areas of these landscapes have a well-buffered top layer (pH > 6.5).

Large parts of the inner dune areas are situated on impermeable layers of peat and clay deposits (figure 2). Infiltrating groundwater stagnates on and flows over these layers. In wet seasons it fills the lower parts of the inner dune landscape. In places where there is calcium carbonate in the subsoil the groundwater is rich in Ca++ ions. These ions buffer the top layer of the humid soil on the lower slopes of the dunes (pH-KCl 5-6.5). When the groundwater flow is too deep or contains too few Ca++-ions, these lower parts have acidic topsoil (pH-KCl < 4).

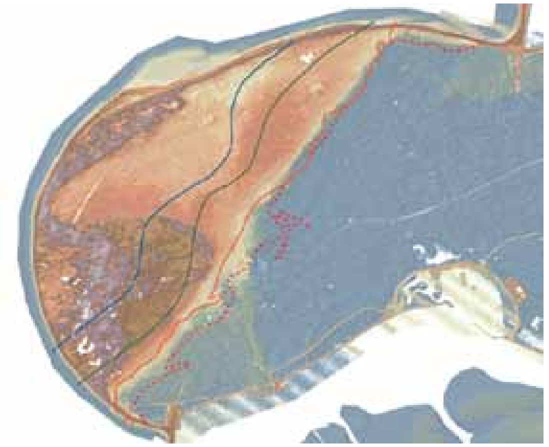

Figure 2

V HISTORICAL DEVELOPMENT

The inner dunes of Walcheren, Schouwen and Goeree belong to the oldest inhabited parts of present-day Southwest Netherlands. They originated as beach plains behind higher dunes and sand barriers (figure 3). They were the nuclei from which the salt marshes were reclaimed and colonized in the 10th and 11th century. This early medieval inner dune landscape, known as 'haaijmetenlandschap' in Dutch, was characterized by the cultivation of rye and buckwheat alternated with grazing, probably on fallow land (Beekman, 2007). Parts of the agricultural land, especially on Walcheren and Schouwen, were planted with coppice alder woodland (Alnus glutinosa) from the Late Middle Ages onwards. The inner dunes of Voorne have a more recent origin, because they were formed in association with the reclamation of salt marshes inland.

Figure 3

On the seaward side the inner dune landscape is bordered by more or less extensive dunes. Until the 20th century these dunes were in a relatively dynamic state. In the Middle Ages and Early Modern Period, parts of the old agricultural land were covered by shifting dunes. These dynamic dunes were owned by feudal lords (e.g. counts of Holland and Zeeland and princes of Orange), who leased them as rabbit warrens and, to a minor extent, also for cattle grazing. In the 18th century, ideas about utilization of the dunes changed. Rabbit warrens were closed down and agriculture and forestry became more important. In 19th and 20th century, differentiation of the land use and spatial development occurred in the inner dunes. This was strongly influenced by local socio-economic circumstances. On Voorne, the dune grasslands in the inner dunes were largely reclaimed and forested. The neighbouring urban environment of Rotterdam played an important role in this development. From a geological and historical perspective the 18th century inner dunes of Goeree are highly comparable to those of Voorne. Local socio-economic circumstances were different however, because of the greater distance to Rotterdam and the more dominant position of local farmers. Here, the characteristic dune grasslands were conserved on a larger scale (Van Haperen, 2009). These differences in historical development during the last two centuries account for differences in Red List species extinctions since 1850.

VI HABITAT TYPES OF THE INNER DUNES

PIONEER COMMUNITIES

Historically, the inner dune landscape has been used intensively by humans. This is one of the reasons why, until recently, pioneer communities were a substantial part of the habitat spectrum of the inner dunes in the Southwest Netherlands. In addition natural dynamics played a role in the form of shifting dunes. The pioneer communities in the inner dunes include several habitat types with different positions along the altitudinal gradient.

Figure 4

Figure 5

In the lowest parts of the inner dune landscape we find water communities and small dune slacks, which inundate in winter and dry out superficially in summer. Especially on Voorne, Goeree and Schouwen they are characterized by basiphilous species (e.g. Characeae, Potamogeton gramineus, Littorella uniflora, Echinodorus ranunculoides, Anagallis minima). In the inner dunes of Walcheren dune slacks are slightly more acidic and have a different species composition (e.g. Osmunda regalis, Gnaphalium luteo-album and Sphagnaceae). Basiphilous species are rare here.

On the upper side of the altitudinal gradient we find pioneer communities of the xerosere (Violo-Corynephoretum). These communities mainly occur in the vicinity of local blowouts, where sand with low concentrations of carbonate is deposited (figure 4). This promotes the presence of species that have a low tolerance for extreme acidity (e.g. Viola curtisii, Jasione montana and several lichen species).

Since the beginning of the last century, vegetation succession has developed strongly in the inner dunes. This is partly due to the termination of agricultural use by humans. The main cause, however, is the drastic change in environmental conditions, such as atmospheric deposition of acids and nutrients, as well as lowering of the groundwater level. As a consequence of these developments the inner dune landscape of the Southwest Netherlands has been largely stable with hardly any blowouts (figure 5). Until recently most dune slacks were covered by a thick layer of vegetation and an acidic top layer, which was rich in nutrients. In the last two decades, however, habitat conditions for the pioneer communities have been restored by restoration projects (Annema and Jansen, 1998; figure 8).

DUNE GRASSLAND

Dune grassland is a major component of the inner dune landscape of the Southwest Netherlands. This has to do with the history of this landscape, in which rabbit and cattle grazing played an important role. It also has to do with the relative flatness of the inner dunes, which goes back to their early medieval origin as low dunes on beach plains and salt marshes. This flatness results in rather gradual and extended gradients in soil humidity and buffering. The inner dune grasslands of the Southwest Netherlands are also characterized by a relatively high nutrient content. This is partly due to the abiotic characteristics of the dune sand (Voorne, Goeree) and partly to the geographical position. The latter is the case on Walcheren, where there is a continuous input of low amounts of beach sand, nutrients and carbonate along the eroding coast between Westkapelle and Domburg. The relatively moist and nutrient-rich environment gives rise to a specific type of dry dune grassland, which occupies an intermediate position between the typical dune grasslands and communities of a more nutritious soil found along the Rhine and Meuse (Festuco-Galietum trifolietosum; Van Haperen, 2009).

Most typical and valuable however, is a humid mesotrophic type of dune grassland that occurs in narrow gradient zones (1-4 metres wide) on the grassy slopes of the inner dunes. The soil of these communities is decalcified and acidic, and is buffered by a groundwater-dependent calcium buffer (see above). There are two different forms of this mesotrophic grassland (figures 7 and 8). The inner dunes of Schouwen and Goeree have a neutral or a slightly acidic top layer (pH-KCl 4-7) rich in species (Botrychio-Polygaletum, with e.g. Polygala vulgaris, Viola canina, Briza media, Spiranthes spiralis, Gentianella amarella and G. campestris). In places with more acidic topsoil (pH-KCl < 4) there is a form of mesotrophic grassland that is less rich in species, with the character of a 'frame community' (Frame community of Danthonia decumbens [Nardetea], with e.g. Danthonia decumbens, Carex trinervis, Carex pilulifera, Hypnum jutlandicum and Rubus vigorosus).

SHRUB- AND WOODLAND

There is a discontinuity in the forest history of the Southwest Netherlands as a consequence of large-scale inundations and coastal erosion that took place in the post-Roman period,. In the Early Middle Ages, there was probably hardly any woodland in large parts of this area. From then on many woodland species had to recolonize the area and particularly the dunes. This process is still ongoing. Since the Middle Ages humans have contributed to this colonization intentionally and unintentionally by introducing trees as well as shrubs and herbs. The woodlands in the inner and outer dunes have therefore developed under great anthropogenic influence. Dune shrubland with Salix repens, Hippophae rhamnoides, Crataegus monogyna and other shrubs are the only natural communities with woody species in the (inner) dunes. The woodland communities with an anthropogenic origin include:

- *Coppice alder woodland (Alnus glutinosa) planted from the 15th century onwards. Plant material was imported from Holland and Flanders, which probably resulted in several other species than alder being introduced in the area (Van Haperen, 2009). The alder trees were coppiced every 5-7 years and at least on Schouwen there was cultivation and grazing between the trees in the first years after coppicing (Beekman, 2007). This type of land use was continued until the first half of the 20th century.*

Figure 6

- *Estates with landscaped parks, lawns and ornamental ponds (figure 6). In the Southwest Netherlands they were established between the second half of the 17th and the end of the 18th century. In the inner dunes several estates were laid out in coppice woodland, which was often incorporated into them. Because the owners of the estates were interested in horticulture and natural history, many plant species were cultivated, e.g. bulb species such as Tulipa sylvestris, Scilla nonscripta and Scilla bifolia. When the attitude towards woodland and nature changed in the 19th century and the management of the estates was extensified, these cultivated species ran wild. At present they form natural populations, offspring of the introduced and cultivated plants ('stinzenplanten': Bakker and Boeve, 1985).*

- *Woodlands recently planted as part of landscape architecture. In the middle of the 20th century landscape architecture became an important instrument in Dutch planning procedures. As a consequence, new woodlands and shrubs have been planted in many places, including the inner dunes. This is a continuing practice. Over the last two decades some hundreds of hectares of new woodlands have been planted on former agricultural land on Walcheren and Schouwen. New woodlands and shrubbery not only serve to turn arable land into an attractive landscape for its own sake, but also to create a good recreational environment for locals and a growing number of tourists in the dune areas.*

VII CONSERVATION MANAGEMENT

STRATEGY

Two conservation strategies can be distinguished in the coastal dunes:

- *Restoration of the dynamic dune landscape on a large scale. Processes like coastal erosion, sedimentation and shifting dunes play an important role in this strategy. Natural processes create the conditions for the habitats and species that belong to the dynamic dune landscape. Conservation of endangered habitats and species in a specified, more stabilized, pattern is of minor importance in this strategy.*
- *Conservation of endangered habitats and species in a specific, more stabilized, pattern. In this strategy, the conservation manager is responsible for creating adequate conditions for the targeted habitats and species.*

Strategy (1) is applied in parts of the outer dunes of the Southwest Netherlands, such as Schouwen. Strategy (2) prevails in the inner dunes. It is combined with the conservation of the cultural heritage present in the landscape and interwoven with other types of land use, such as recreation (campsites), forestry and the extraction of drinking water.

HYDROLOGY AND SOIL

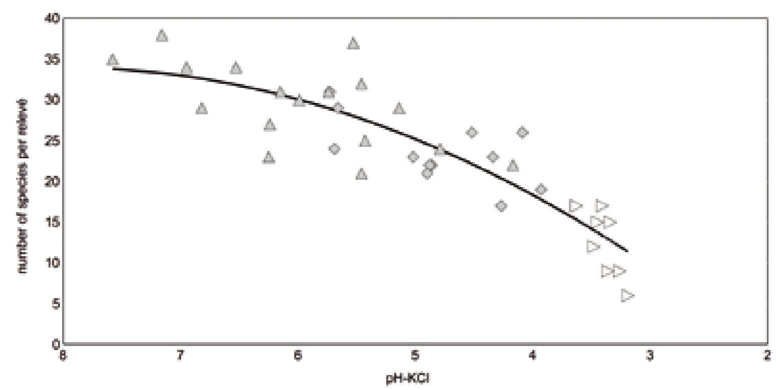

Figure 7

Buffering of acidity is a dominant determinant of biodiversity in many habitats, including the inner dunes (Figure 7). The measure of acidity can determine the availability of nutrients (Kooijman & Besse, 2002). The pH is therefore not only of importance for abiotic soil-conditions, but also influences productivity, vegetation structure and vegetation succession. It is therefore of major importance for a conservation manager to maintain and, if necessary, restore the mechanisms that buffer the pH in the top layer of the soil. The measures that need to be taken in a specific location depend on the local abiotic situation – initial carbonate content, rate of decalcification, hydrology, presence of geomorphologic dynamics, presence of bioturbating animals etc. In general, two sets of measures are adequate: (1) directly influencing the pH by hydrological or geomorphologic measures and (2) reducing the amount of acidifying H+ ions by reducing the amount of decomposing organic material.

RESTORATION MANAGEMENT

Figure 8

Especially over the past decades ecological conditions in the inner dunes of the Southwest Netherlands have changed dramatically, due to changes in land use, lowering of the groundwater levels and environmental pollution. As a consequence, vulnerable habitats with a high diversity in species degenerated. In some areas, however, the degeneration has remained manageable, so the ecological conditions could be restored or at least improved. The following measures have been taken:

- *Removal of acidified sods in small dune slacks in order to restore basic mineral soil conditions. The combination of this measure and subsequent grazing or mowing enabled re-establishment of populations of basiphilous species such as Epipactis palustris and Parnassia palustris, which had already disappeared 20-40 years earlier (figure 8).*
- *Filling up local ditches and trenches reduced water drainage. This produces high groundwater levels, especially during wet winters, and thus contributes to the buffering of acidifying soils higher up the slopes of the dune slacks. This buffering is most effective when inundations occur once every 1-3 years, although never for prolonged periods, as certain basiphilous species (e.g. Parnassia palustris) are susceptible to prolonged inundations.*
- *Removal of the acidified top layer of grasslands in the xerosere and experiments with the regeneration of local blowouts. This is a way to restore less acidic conditions in dry soils (figure 4). The ultimate results of this type of restoration obviously depends on the concentration of calcium carbonate in the subsoil.*

GRAZING AND MOWING

The inner dunes of the Southwest Netherlands have a long history of rabbit, cattle and horse grazing. Agricultural grazing ended by the middle of the 20th century. In the early 1950s rabbit populations were dramatically reduced as a result of myxomatosis. These populations largely recovered in the 1950s and 1960s and up to the 1980s the inner dunes were densely populated by rabbits. In the early 1990s rabbits disappeared almost completely, probably because of Viral Haemorrhagic Disease. There has been no significant recovery of rabbit populations in the inner and outer dunes of the Southwest Netherlands since then.

After the ending of agricultural grazing, conservation management has introduced grazing as a means to conserve and restore specific habitats. Additional mowing takes place locally. Mowing dune grasslands is used only locally as an independent conservation technique and is of minor importance.
The primary goal of grazing and mowing is an open vegetation structure that offers opportunities for thermophilous species to germinate and reproduce. The removal of organic material from the ecosystem in order to influence the pH of the topsoil is an important additional goal. Lastly, grazing and mowing may contribute to the dispersal of diaspores and thus enable the development

of vital populations and metapopulations of endangered plant species. This contribution is most effective when grazing is applied in large areas where animals can roam through various parts of the dunes and various habitats. Grazing is therefore typically extended over large, continuous areas. In a heterogeneous dune area where cattle have a lot to choose from, however, this can result in too little grazing in certain parts of the area. Additional grazing within portable fences or additional mowing can be practised to make up for this deficit when vulnerable species or habitats are involved.

WOODLAND MANAGEMENT

Because of the hiatus in the forest history of the Southwest Netherland and their anthropogenic origin, the woodlands of the inner dunes are less important to biodiversity than the communities of the open inner dune landscape (e.g. dune grasslands and pioneer communities). Nevertheless, they are part of the historical heritage and contribute greatly to the scenery and spatial structure of the inner dune landscape. They are also very important as a recreational environment for tourists and locals alike. Woodland management therefore primarily targets the scenic and recreational qualities of these woodlands. Specific biodiversity goals play only a minor role, but old trees are protected as a habitat for certain species of birds and bats, for instance.

VIII FINAL REMARKS

The inner dune landscape of the Southwest Netherlands has a long history and contains great biodiversity. Humans have played and important role in the historical development of this landscape and in creating the conditions essential for habitats and species typical of this region. Over the last century human land use has changed dramatically and this has had major consequences for these habitats and species. The results that conservation management has achieved suggest that it is possible to conserve the characteristic biodiversity of the inner dune landscape for future generations. Human intervention, now in the form of conservation management, remains as important as it has been for centuries.

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▸ *Fig. 1. Topography of the coastal area of the Southwest Netherlands*

▸ *Fig. 2. Geomorphology of the dune area of Schouwen. The difference between outer dunes (SW) and inner dunes (NE) is clearly visible. The dark lines on the map indicate from east to west: (1) landward border of the dune sand (dotted line); (2) landward border of dune sand layers with a depth > 2m; (3) seaward border of clay deposits in the subsoil; (4) seaward border of peat deposits in the subsoil.*

▸ *Fig 3.Beach plain of the Kwade Hoek (Goeree). The present inner dunes of the Southwest Netherlands probably looked like this in the Early Middle Ages.*

▸ *Fig.4. Blowouts can contribute to the buffering of topsoil layers and an open vegetation structure. The Violo-Corynephoretum is a typical community here.*

▸ *Fig. 5. The inner dune landscape of the Middelduinen (Goeree). This dune area is largely stable and hardly any blowouts occur. It still has a high biodiversity however, because of the presence of calcium carbonate at a depth of 50-100cm.*

▸ *Fig. 6. Avenue with beeches on the estate Berkenbosch (Oostkapelle, Walcheren). This avenue was constructed around 1700, when the medieval coppice alder woodland was partly covered by shifting dune sand. New alder woodlands were subsequently planted.*

▸ *Fig. 7. Relation between acidity and number of species per relevé in different types of humid mesotrophic grassland. Grey icons: different forms of the Botrychio-Polygaletum; white icons: Frame community with Danthonia decumbens [Nardetea] (Van Haperen, 2009).*

▸ *Fig. 8. Distribution of two different types of humid mesotrophic grassland in the inner dunes of Schouwen. Left: Botrychio-Polygaletum; right: frame community with Danthonia decumbens.*

▸ *Fig. 9. Inner dune area of the Vroongronden (Schouwen) approx. 10 years after a restoration project. Acidified sods have been cut in the low dune slacks. Basic mineral conditions were re-established after some wet winters and several basiphilous species returned. Grazing can maintain a low and open vegetation structure for a longer period.*

4

Project to restore dry grassland in agricultural lands

located between the Ghyvelde decalcified dune and polder in Les Moëres, France

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ABSTRACT

French Départements are decentralized local communities that have been judicially empowered to implement nature conservancy policies since the 1960s. Départements have the right of pre-emption on lands (natural areas) in defined zones. In Département du Nord territory (near the Belgian border) the community Département du Nord (Nord Départmental Council/ Conseil général du Nord) is closely associated with the Conservatoire de l'Espace Littoral et des Rivages Lacustres (CELRL – French Coastal Protection Agency) for the preservation and the management of the coastal heritage.

Département du Nord has conducted restoration and management experiments since December 2004 on land in Les Moëres municipality owned by the CELRL. The goal of these experiments was the restoration of dry dune grassland and mesotrophic meadows in 8.2 ha of former agricultural lands situated in the transition zone between polders and the Ghyvelde decalcifed dune. This dune which is 5000 years old and has been cut off from the sea since the last ice age, supports unique biological communities bound by decalcified sands. The beautiful complexes of dry and acidocline grassland are considered to be habitats whose conservation is a top priority for European authorities.

The dune and the lands included in the area between dune and polder were selected to fit into the Natura 2000 network as a Zone of Special Conservation (ZSC). A small part of this area was included in a special restoration project and the organic topsoil was removed over an area of about 4 ha. So far, after 5 years of natural and spontaneous recolonization, responses to the results are guarded. Some parts of the local vegetation are characterized by the development of nitrophilous sandy species such as Common Velvet Grass (*Holcus lanatus*), Flatweed (*Hypochaeris radicata*) or by Ragwort (*Senecio jacobaea*). The presence of Ragwort was encouraged by unregulated overgrazing by horses. The goal of the initial project of extensive horse grazing was to reduce the growth of weeds facilitated by the fertility of the soil caused by prior cultivation of potatoes and corn. But the uncontrolled grazing help neither the development of the specific or rich dune vegetation and this evaluation... With time, we hope to be more successful. We did however noticed the presence of a more characteristic vegetation composed of Red Sorrel (*Rumex acetosella*), Common Alkanet (*Anchusa officinalis*), Hair-cap moss (*Polytrichum juniperinum*) and Cup Lichen (*Cladonia sp.*) in several places and decided to stop the overgrazing. In the created ponds, we also found Brookweed (*Samolus valerandi*) and some Stonewort (*Characea sp.*). During the summer of 2010, Département du Nord sought the expertise of the Centre Régional de Phytosociologie de Bailleul to precisely analyze the vegetation in place and assess its ecological value, as well as its value in comparison with the acidic vegetation in the nearby dune. This monitoring provided us with a transitional assessment for future evaluations and shows the success of this experiment. This experiment also demonstrates the political will to restore natural areas in strategic areas within a strong agricutural context.

Keywords: *Decalcified dune, Acidic sands, Dry dune grassland, Over-grazing, Soil exportation, Vegetation monitoring.*

II GENERAL CONTEXT

Le Conservatoire de l'Espace Littoral et des Rivages Lacustres (CELRL) has been managing the shores of the Département du Nord for the last 25 years and has set up some ambitious policies regarding the restoration of dune habitats, in particular the Ghyvelde fossil dune and its surrounding areas.

This fossilized 600 ha dune is now situated inland, about 3km from the sea in the Flemish maritime plain. It marks out the old shoreline that existed before the drop in sea levels caused by a fall in temperature and the expansion of the ice cap. Cut off from the shore for the last 5,000 years and no longer receiving the regular debris of calcareous shells, this dune bar has become progressively acidic as its calcite (shelly limestone) content has leeched away and in consequence a habitat particular to the area has developed.

Figure 1. General view of Ghyvelde dune

The conservation of this complex habitat of dry dune grassland is deemed to be a priority under the Habitats Directive (Council Directive on the conservation of natural habitats and wild fauna and flora) of the European Union. The goal of the first management operations was creating an extensive equine pasture, which, it was hoped, would eliminate anthropic and exogenous afforestation with nitrophilous tendencies. Due to succession and allowing the land to lie fallow, this threatens the continued existence of the dune grassland. Furthermore, the total elimination of these trees, scattered over 40 ha would allow a significant expansion of the acidophilous grasslands, which are extremely scarce on a regional scale and very limited on a European scale.

Additional inventories of invertebrates have also revealed the presence of a mollusk, *Vertigo angustior*, which is of great international importance. Recorded in appendage II of the Habitats Directive, the presence of this species, in nitrophile vegetations, and indeed, exogenous habitats, raises the question of priorities and relevance in management choices, especially as regards the "naturalness" of the species at least in the habitats in which it is found.

III BASIC INTERVENTION

The natural heritage site managed by Département du Nord consists of 711.4 ha (data of 14 May 2010) of dunes situated on the east -coast of the Dunkirk area, close to the Belgian border. It consists of the Ghyvelde fossil dune and a group of nearby onshore dunes. The Ghyvelde fossil dune is the object of a politically ambitious acquisition on the part of the French Coastal Agency (CELRL) with the help of the Nord Départmental Council through the creation of a pre-emption zone under the title of the policy "Espaces Naturels Sensibles", implemented by a declaration of public utility (DUP) on the central part of the dune and private negotiations for land outside the pre-emption areas. The acquisitions of these two bodies are dedicated to preserving the basic heritage of CELRL

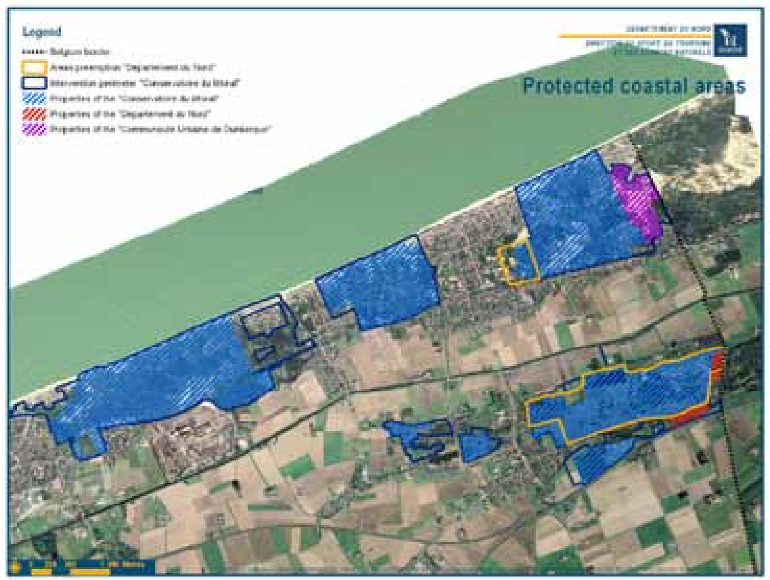

Figure 2. Localization of protected coastal areas on the east coast of Dunkirk

Accordingly, the Nord Départmental Council decided to acquire a first piece of land (18.66 ha) on 17 November 1986 and to create the pre-emption zone in the eastern sector of the dune on 24 November 1986 over an area of approx.150 ha.

Over the years Département du Nord acquired 112.4 ha at the heart of the pre-emption zone and 19.1 ha close to the pre-emption zone. After preserving the most outstanding part of the site the Département carried out more private acquisitions, without any compulsory purchase orders, on the western part of the dune. This consisted of 17.2 ha acquired in 2006.

CELRL implemented a declaration of public utility on the central part for 40 ha of the fossil dune (es) transformed in estearn sector on 15 March 2004 and became the owner of 36.1 haon 28 June 2005. Finally CELRL took on the responsibility for some old property of the Ministère de l'Equipement(Ministry of Transport). This consisted of land in the Moëres municipality enclosed between the Ghyvelde fossil dune and the coastal bypass (motorway A16), which links the towns of Dunkirk and Ostend. This land, situated in a dune-polder transition zone, connects an old sand quarry (Lac des Moëres, 13.2 ha) created for the construction of the motorway and approx. 8.2 ha of agricultural land. The transfer of the property to CELRL took place on 15 November 2002. A total area of 200 ha of fossil dune and surroundings has now been protected by land purchases.

The restoration experiment presented here involves returning this land, which was recently used for agriculture, to its natural state. Before describing the works and the results, it would appear opportune to examine the riches of the fossil dune, and the management objectives and work undertaken in order to understand the context and objectives of the restoration and to identify the nature of the vegetation we hope to see develop over the medium or long term.

IV DESCRIPTION OF THE FOSSIL DUNE: PLACE REFERENCE

Situated in the Flemish maritime plain, the fossil dune and the dune polder transition zones are situated in the municipalities of Ghyvelde and Les Moëres 3km inland from the sea. The site is listed in the French Natura 2000 network as a Zone of Special Conservation (ZSC no. FR3100475).

The dune covers a geological area of about 400 ha in France, 177 ha of which belongs to the CELRL (eastern sector) and 17.2 (western sector) belongs to Département du Nord, but is expected to be transferred to CELRL. The site is elongated in form, running parallel to the coast and positioned west-south-west/east-north-east. The dune has a height of +4m NGF with a maximum point of 13.3m to the north of La Dune aux Pins" medical centre, located near the Belgian border. The dune continues into Belgium for 200 hectares in the municipality of De Panne (Adinkerque) with the name of Cabour Domain. The total surface of the historical (geological) fossil dune is 600 ha.

This fossil dune was created 5,000 years ago in the Flandrian era. It marks the old shoreline that disappeared following the drop in temperature and the extension of the polar ice cap. In time, the lack of marine deposits and the leeching of the shelly limestone led to decalcification of the marine shells contained in the sand, particularly in the dune's upper layers of sand.

This progressive decalcification has favoured the establishment of a highly unique flora and vegetation communities linked to the decalcified sand, in particular the vegetation of dry grasslands with more acidic substrates. These provide several habitats of major national interest: dune grasslands of *Phleo arenarii-Tortuletum ruraliformis,* Broad-leaved Thyme (*Thymus pulegioides*), Common Rockrose (*Helianthemum nummularium subsp.obscurum*), pioneering acidocline to acidophile dry grasslands [*Violo dunensis-Corynephoretum canescentis* and *Festuco filiformis-Galietum maritimi*], areas of Sand Sedge (*Carex arenaria*), Common Sheep Sorrel (*Rumex acetosella*) and also Sheep's Bit (*Jasione montana*) and Early Sand Grass (*Mibora minima*) (Basso et al., 2000; Basso, 2002). Moreover, bryophytic flora and well-developed lichens are very typical of these herbaceous communities, depending on the amount of pH in the soil. Also recorded are *Cladina ciliata, C. portentosa* and *C. arbuscula* as well as *Cladonia cf. glauca* or *C. subulata* and *Cladonia foliacea* (Diederich Paul, personal communication, 2002). For the most part, the vegetation of the Ghyvelde dune (appendage I of Directive 92/43 CE) consists of remarkable phytocoenosis from the point of view of rarity and/or vulnerability at the regional level of the Région Nord/Pas-de-Calais and at European level. The protection of this site is justified by the Habitats Directive (Basso et al., 2000; Basso, 2002).

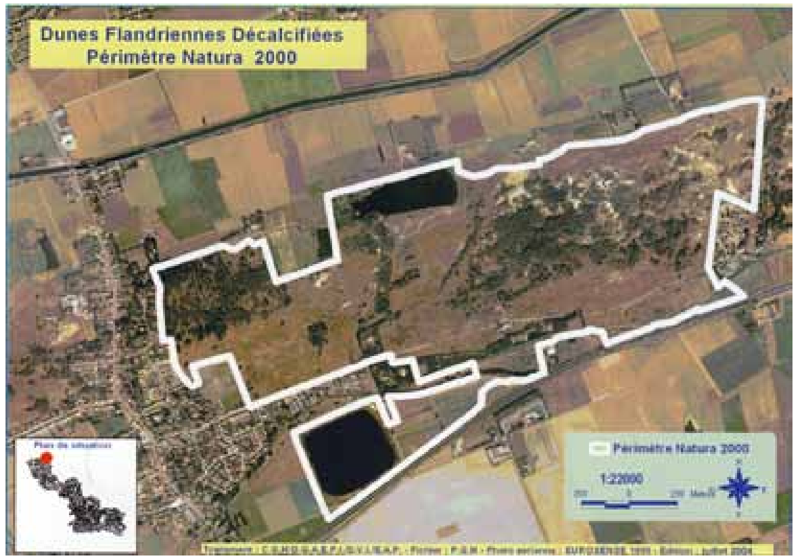

Figure 3. Natura 2000 network area for Ghyvelde decalcified dune

Since 1994 Département du Nord, the old owner and present manager of the 200 ha area that now belongs to CELRL, has been concerned about the effect of the dynamics of the spread of Reed Grass (*Calamagrostis epigejos*) and with the gradual dispersal of Sycamores (*Acer pseudoplatanus*) over the dry grasslands. In dense and monospecific populations the Reed Grass threatened areas of Sand Sedge (*Carex arenaria*), Shepherd's Cress (*Teesdalia nudicaulis*) and Yellow Hairgrass (*Aira praecox*), as well as sparse groups of bryolichens. The area covered by these systems extends to 35-40% of the dune (Lemoine et al., 2001). Other habitats of less interest are the more or less nitrophile meadows or herbaceous edge, thickets of Sea-Buckthorn (*Hippophae rhamnoides*) and wild privet mixed with elders and with wooded areas made up of Canadian Poplars (*Populus x canadensis*) mixed with Sycamores (*Acer speudoplatanus*) and in the west of the dune the occasional Scotts Pine (*Pin sylvestris*). Also found here is a remarkable species of mollusk: *Vertigo angustior*, discovered in the mid 1990s by Michel Geniez (Biotope, 1996). The most recent findings (Cucherat et al., 2006; Cucherat et al., 2007) reveal that the species prefers groups of vegetation that are herbaceous and heliophile, and more or less nitrophile such as Stinging Nettles (*Urtica dioica*) and Goosegrass (*Galium aparine*). These habitats are not characteristically or specifically dune environments. The species exists mainly in the interfaces between wood and meadow and wood and grassland and its presence causes much debate on management principles and the appropriateness of removing anthropic woodland, based on old poplar cultivars.

V MANAGEMENT THROUGH GRAZING

In order to restore the dune grasslands, Département du Nord and CELRL worked with a breeder of hardy horses (Haflinger breed). An enclosed area of 70 ha was made freely available on condition that there would be no other supply of fodder or additional feeding and no treatment of the 12 animals introduced in 1995. This agreed collaboration stopped the growth of Reed Grass (*Calamagrostis epigejos*), reduced the volume of straw and the number of summer fires and slowed down the spread of woodland. The restoration of the short grasslands led to the discovery in 1998 of the Early Star of Bethlehem (*Gagea bohemica*), the nesting of Wood Larks (*Lullula arborea*) and the maintenance of the European Stonechat (*Saxicola rubicola*) and Northern Wheatear (*Oenanthe oenanthe*). The restoration was equally good for numerous other species, notably invertebrates (*Orthoptera*) and also led to the appearance of a very rare mushroom (*Poronia erecti*), which developed on the rabbit and horse droppings. In 1999 a further 20 ha was given over to pasture on the same site and 20 animals grazed the whole site. The work of the horses is complemented by rabbits, which have adapted to the cleared terrain (Lemoine et al., 2001). Experiments in sheep grazing are also taking place on areas situated on the edge of the dune. After a phase of positive restoration over most of the site, a level of grazing that was too intensive or badly organized resulted in the deterioration of the grasslands, the rapid spread of Ragwort (*Senecio jacobaea*) and the death of several horses through poisoning by senecionine, a pyrrolizidine alkaloid found in the Ragwort (Lemoine, 2009). Faced with this situation the number of horses was greatly reduced and a programme of Ragwort removal was undertaken.

Figure 4. Horse grazing in decalcified dune of Ghyvelde

VI RESTORATION WORKS IN THE DUNE-POLDER ZONE

In the winter of 2002 the agricultural land near to the Ghyvelde fossil dune, which had been transferred from the Ministère de l'Équipement (Ministry of Transport) to CELRL, became available for integration within the Sensitive Natural Spaces (Espaces Naturels Sensibles) policy and for a return to its natural state. The land was to be transformed in December 2004 into dune grasslands or into mesotrophic meadows, when the fertility of the ground was too rich. Taking into account the scale of earlier agriculture (cultivation of cereals and potatoes) it was decided to remove the topsoil. A bulldozer was used to remove 15cm of humus - rich earth on the surface, revealing poorer, sandier soils below containing fewer fertilizing elements. The removed earth was moved to the southern extremity of the area to create a small embankment and protect the site from the motorway. Taking account of the cost (50,000 euros plus tax) the topsoil was removed only in the eastern sector (4 ha), leaving the western sector untouched.

Figure 5. Embankment near the motorway (Dec 2004)

Figure 6. Final appearance after works (Dec 2004)

Figure 7. Pool and the removed organic topsoil in December 2004

These earthworks were accompanied by the creation of a series of dune pools, thus improving the diversification of the habitat and providing vulnerable animals with water and amphibians and aquatic insects (dragonflies) with the means for reproduction.

The ground was not reseeded and it was decided to allow recolonization to occur naturally and spontaneously on what had been agricultural land. Management hoped that the area would be recolonized by seeds carried by the wind from vegetation on the Ghyvelde fossil dune. An extensive grazing program was also implemented in 2007 to limit the nitrogen-hungry plants, which had previously been present. Rather than two horses, the breeder disregarded the recommendations of the Départment and grazed a much greater number of horses (up to eigth), supplementing them with fodder.

VII RESULTS

After 5 years of natural and spontaneous recolonization,responses to the results are guarded. An initial observation shows that the vegetative structures correspond to those of dune grassland. All surface vegetation is low vegetation, dominated by moss, grasses and small weeds. The site also consists of numerous bare and scorched zones (without any vegetation) caused by the intense action of rabbits. In these areas we also observed the Northern Wheatear (*Oenanthe oenanthe*) displaying nesting behaviour, but without reproduction being confirmed. The local vegetation is, however, characterized by the development of nitrophile sandy species such as Vernal Whitlow Grass (*Erophila verna*), Common Evening Primrose (*Oenothera biennis*), Common Velvet grass (*Holcus lanatus*) and Flatweed (*Hypochaeris radicatas*). In this extremely close-cropped environment, one species grows up high: Ragwort (*Senecio jacobaea*). Its presence was encouraged by unregulated overgrazing by horses and rabbits. The extreme poisonous nature of the plant allowed it to escape consumption by either the domestic or the wild herbivores (rabbits) and to gradually spread over the available space.

Figure 8. Ragwort (Senecio jacobaea) extension; the negative consequence of overgrazing by horses.

Figure 9. Transition zone after 5 years' work.

With time we hope to be more successful; we noticed have however the presence of more characteristic vegetation composed of Red sorrel (*Rumex asetosella*), Common Alkanet (*Anchusa officinalis*), common Hound's-tongue (*Cynoglossum officinal*), Juniper Hair-cap moss (*Polytrichum juniperinum*), lichen (*Peltigera rufescens*) and Cup Lichen (*Cladonia fimbriata and C. furcata*) in several places, with some delicate Bird's-foot (*Ornithopus perpusillus*), Hare-foot clover (*Trifolium arvense*), Changing Forget-me-not (*Myosotis discolor*) and Early Forget-me-not (*Myosotis ramosissima*), dune' Stork's-bill (*Erodium cicutarium subsp dunesis*). This kind of vegetation is more specific to the dry grasslands of the Ghyvelde dune or of acidic and mesotrophic soils. In the ponds, we also found Brookweed (*Samolus valerandi*), some Stonewort (*Chara aspera*) and Common water-crowfoot (*Ranunculus aquatilis*). We found also two species typical of agricultural soils: Corn Spurrey (*Spergula arvensis*) and Field violet (*Viola arvensis*).

VIII COMMENTS

The results of a quick analysis prior to the spring of 2010 were inconclusive. After 5 years of natural and spontaneous recolonization, the gramineous species of the nearby dune such as Silbergras (*Corynephorus canescens*) and Sand Sedge (*Carex arenaria*), have not been found. The first reason is perhaps overgrazing in the two areas. Uncontrolled grazing in the transition zone between dune and polder did not help the development of the specific or rich dune vegetation. All new vegetation that tried to colonize was eaten. So, overgrazing caused the systematic destruction of leaves and flowers (except toxic species) and did not help the evaluation and botanical recording. Faced with this situation, we decided to stop overgrazing. An injunction was served on the horse-breeder and half of the area was fenced off. Likewise, overgrazing in the nearby decalcified Ghyvelde dune did not help the spontaneous recolonization of this former agricultural land. The destruction of flowers and grasses (e.g. *Carex arenaria*) did not help the spread of seeds. The very large population of rabbits present on the site is another possible factor. At the time of the initial work, very small contours (ditches, slight rises) were created in order to diversify the ecological micro-conditions. These, plus the embankments around the edge of the site, also provided the opportunity to create favourable areas for their reproduction.

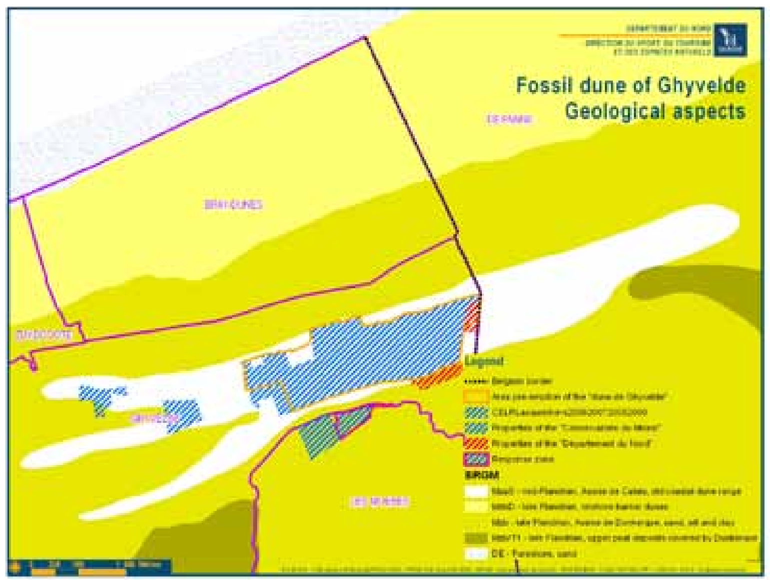

Figure 10. Geological aspect of the site experiments and around

A second reason for this disappointing result is perhaps the nature of the land on which the experiment was carried out. It is a transition zone between dune and polder, so the nature of the substrate is probably very different. According to the geological map the subsoil of this sector is different from that of the decalcified dune. The soil here corresponds to more recent deposits from the late Flandrian (Assise de Dunkerque Mzb), whereas the soil of the fossil dune is exclusively sand deposited in the mid Flandrian (Assise de Calais, MzaS). This geological peculiarity, a mixture of sand, silt and clay, would explain the much weaker potential in this sector (Blondel, 2009). However, a comparison with a nearby sector with identical soil provides hope that the site will be colonized by Colonial Bentgrass (*Agrostis capilaris*), which forms another kind of short acidic grassland, and the ending of overgrazing by horses resulted in the identification of new and interesting species in May 2010 (e.g. *Myosotis* sp., *Spergula arvensis*).

IX CONCLUSION

During the early summer of 2010, Département du Nord sought the expertise of the Centre Régional de Phytosociologie de Bailleul to precisely analyze the vegetation in place and assess its ecological value, as well as its value in comparison with the acidic vegetation in the nearby dune. This monitoring provided us with a transitional assessment for future evaluations.
This inventory (Blondel, 2010) brought some surprising and positive results. Contrary to all expectations, the site has produced some very beautiful annual lawns and dry grasses of *Thero-airion* to *Aira praecox, Aira caryphyllea and Vulpia bromoïdes*, which join *Aphanes australis, Hypochaeris glabra, Vicia lathyroides, Trifolium striatum* and *Carex arenaria* . We also found very beautiful populations of Bird' s-foot (*Ornithopus perpusillus*). Numerous species were also found in the ponds. The most characteristic are *Salix arenaria, Juncus subnodulosus* (protected species in the Nord Pas de Calais region), and *Isolepsis setacea*.Taken as a whole the site presents a very interesting complex of acid dry lawns of the appendage I of the Habitats Directive and demonstrates the success of this experiment.

With time we hope that the vegetation will continue to spread and form a rich and original vegetative community to complement the range of dry grasslands presently found on the coast of Dunkirk. This experiment also demonstrates the political will to restore natural areas in strategic sites (Natura 2000 network) within a strong agricultural context. Clearly the sector of Maritime Flanders on both sides of the Franco-Belgian border is an intensive agricultural zone and the area of woodland and wild spaces around actually Dunkirk accounts for less than 3% of the total area.

Figure 11. Acidic dry grassland with Aira praecox and Polytrichum juniperinum (June 2010)

Figure 12. General view of the site in June 2010.

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5

Transitional habitats and coastal species in England:

their conservation value and management

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I ABSTRACT

The 2008 framework for delivery of the England Biodiversity Strategy puts a strong emphasis on the integration of action to achieve biodiversity targets for habitats and species listed in the UK Biodiversity Action Plan (UK BAP). Large, landscape scale approaches are specifically encouraged, moving away from site or individual species-focused actions. The availability of guidance to achieve these challenging objectives is limited. Habitat management guidance is based on achieving an 'ideal' combination of vegetation communities, whereas the wide range of variation at the margins where transitions to other habitats occur is less well-defined in guidance.

For coastal habitats in particular, which support a high number of UK BAP species for their limited extent, there are many potential types of transitions, and many support rare species. These species have life histories that enable them to occupy niches that are now rare due to extensive truncation of natural transitions or increasing stabilisation of coastal systems. To meet biodiversity targets, habitat restoration projects with objectives for multiple species and habitats need to consider the transitions between habitats, not only the more 'typical' habitats, as this is often where the niches for rare species are found. Dynamic processes and natural colonisation strongly influence the distribution and development of coastal and transitional habitats, and there are some key examples on the English coast which illustrate how habitat transitions over time and space can support rare species. Bare ground, hydrology and sediment movement are highlighted as key factors for species. Understanding and learning from these more natural systems is important, and requires acceptance that making better use of nature may not guarantee specific outcomes against defined targets.

The impacts of climate change may also be less defined: the adaptive management of the coastal zone will need to take account of this. This review paper brings together a range of information to identify the key aspects of guidance and information that need to be developed to assist effective landscape-scale delivery of biodiversity targets in England, and encourages a wider perspective across specialisms.

Keywords: *coastal habitats; rare species; management; transitions; sand dune; saltmarsh*

II INTRODUCTION

The first UK nature conservation legislation in the late 1940s was based on protecting sites and species. The establishment of Sites of Special Scientific Interest (SSSIs) for features of special interest was a key mechanism that still underpins nature conservation in the UK today. Towards the end of the 20th century, increased interest in habitats and species outside these sites, driven by European and international legislation and conventions, led to the consideration of how sites functioned as a network and species and habitat status across their whole range. The publication of the UK Biodiversity Action Plan (UK Biodiversity Group 1994) in 1994 complemented the purpose of the 1992 EU Habitats Directive to maintain or restore favourable condition of important habitats and species across their whole range.

The UK BAP included a list of 391 'priority BAP species' which were selected according to criteria such as known declines in populations. In addition, 45 'priority BAP habitats' were identified on the basis of criteria of international importance, rapid decline and high risk. The habitats were defined as part of this process (UK Biodiversity Action Plan 2008), and correspondence to Annex I habitat types has been developed by the Joint Nature Conservation Committee (JNCC) (http://www.jncc.gov.uk/default.aspx?page=1425 [accessed June 2010]), al-though these do not correspond exactly. Priority habitats and species each had an action plan (HAP/SAP), published in tranches between 1995 and 1999, setting out the issues, targets and mechanisms for maintenance and recovery. Table I shows the coastal BAP priority habitats (UK Biodiversity Group 1999) and the UK targets and latest report from 2008 on progress towards the targets.

TABLE I. COASTAL BAP PRIORITY HABITATS

Priority Habitat	2006 Targets summary	2008 UK BAP report
Coastal saltmarsh	No net loss; create habitat to offset historic losses; improve condition of unfavourable habitat	Declining: continuing/ accelerating
Coastal vegetated shingle	No net loss; improve condition of unfavourable habitat; initiate restoration from arable land in key locations	Declining: continuing/ accelerating
Maritime cliff and slope	Maintain free-functioning resource (no net loss); no loss to coastal engineering works; increase extent unaffected by coastal engineering; increase extent of cliff top habitat.	Declining: continuing/ accelerating
Coastal sand dune	No net loss; improve condition of unfavourable habitat; control natural succession to scrub/ woodland	No clear trend
Machair *(Scotland only)*	Original 1999 targets: maintain extent. Restore improved machair grassland; reduce over-grazing; restore sites degraded by sand extraction.	Stable

To ensure that the UK BAP remained focused on the correct priorities for action, and takes account of changes in status of habitats and species, a review of the list was undertaken in 2007, (BRIG 2007) with a new UK list of 1150 species. Revisions to the habitats increased the number to 67 BAP priority habitats in 65 plans (some habitats are grouped).

As existing priority habitats, the coastal BAP priority habitats remained on the list as shown in Table I. Individual Species Action Plans (SAPs) for the increased number of species were not considered a feasible option. Instead, due to greater recognition of the close relationship between habitat and species conservation needs, effort was put into moving towards a habitat based approach for the conservation of species, linking action needed with the BAP priority habitats.

Delivery of UK BAP action for habitats and species is now devolved to the country administrations. Each country (Scotland, England, Wales and Northern Ireland) has developed a biodiversity strategy.

In England, the England Biodiversity Strategy (England Biodiversity Group 2008) is taking forward a suite of work that contributes to the UK BAP. This work promotes a much wider ecosystem approach. Its aims include the need to:

- *Encourage the adoption of an ecosystem approach and embed climate change adaptation principles in conservation action,*
- *Achieve biodiversity enhancements across whole landscapes and seascapes,*
- *Achieve our priority habitat targets, placing an emphasis on habitat restoration and expansion,*
- *Enhance the recovery of priority species and better integrate their needs into habitat-based work.*

Part of this new framework is the concept of 'Integrated Biodiversity Delivery Areas' (IBDAs). These areas are intended to be large (10,000 to 25,000 ha) and cover a wide range of habitat types and species. IBDAs will be areas where biodiversity gains will be delivered through:

- *Achieving better condition of existing BAP habitats and wider linking habitats, so they can better support the full range of BAP species present.*
- *Achieving better quality habitat restoration and expansion, by incorporating the needs of the full range of BAP species present in, or likely to colonise, an area from the start.*
- *Targeting restoration and expansion to create the best habitat networks possible, in order to maximise resilience to our changing climate.*
- *Working across the full range of habitats present, to maximise the benefits to the many species that are dependent on habitat mosaics or edges.*
- *IBDAs will also be carefully monitored to assess the outcomes of this approach for biodiversity and ecosystem services, to learn lessons for biodiversity delivery elsewhere.*

These principles emphasise the importance of mosaics and transitional habitats. Coastal habitats and their transitions to wetland and terrestrial habitats and the species they support will be covered by IBDAs. The authors of this paper are all part of the Coastal Biodiversity Integration Group (Coastal BIG). A key role of this group is to identify species-based success measures for habitats (including habitat context and connections with other habitats) and knowledge gaps that need to be addressed.

One of the issues identified is how to make better links between management for habitats and species. To date, management for habitats has primarily focused on those types that 'fit' with vegetation classification systems such as the National Vegetation Classification (NVC) (Rodwell 2000). Although this makes use of plant species to define communities, it does not make use of other species, often rare or scarce, in the classification. Although not part of its intended application, the NVC can lead to situations where habitat management guidance has often been based on the objective of achieving a more homogenous stand of vegetation that can 'fit' within the classification, rather than consideration of the habitat structure or non-biological elements such as bare ground or hydrology.

This move towards 'landscape scale' measures for nature conservation cutting across habitat boundaries will require information and guidance for land managers from a range of sources. Management is currently delivered at a site scale, often focused on individual habitat or species features. Guidance and information is needed if the approach is to be effective in delivery of actions and benefits for habitats and species, particularly those which occur as transitions between habitats and are not clearly defined by standard habitat classifications.

III TRANSITIONAL HABITATS AND SPECIES REQUIREMENTS

Habitat classifications such as the National Vegetation Classification (Rodwell 2000) are based on samples taken from homogenous stands of vegetation and rarely focus on the transitions between communities. Where sample numbers are limited, as is the case with many saltmarsh communities, the classifications are potentially less effective at capturing the whole range of variation, for example saltmarsh in Scotland is not well described by the NVC (S. Angus, pers comm.). A potential outcome is that habitat types which fall between the 'standard' descriptions are likely to be less valued, although there is evidence that these can provide important niches for many species. For saltmarshes in particular, much of the upper marsh vegetation was not included in the coastal volume (Rodwell 2000). Other grassland or swamp/mire types with a brackish element were included in non-coastal habitat descriptions (Rodwell 1992, 1994) As a result, some of the most interesting vegetation from a biodiversity perspective has not been covered, and not considered at either the local or national scale in preparing management strategies and plans (P. Adam pers comm.).

Management guidance is also often focused on an end-point of achieving the main habitat type, rather than considering successional phases during restoration. For example, heathland management is often geared towards achieving a high cover of open, dwarf-shrub heath, yet species requirements are for bare ground, scrub and shelter (provided by trees) (Webb et al. 2010). As a consequence, species such as nightjar (*Caprimulgus europeaus*) can successfully nest where initial restoration from tree cover causes large areas of open ground, but are displaced as restored heathland develops to closed canopy of dwarf-shrub heath (A. Drewitt, pers comm.).

This is one of several issues to address about the use of measures to inform successful integration of habitat and species' management (Webb et al 2010):

HABITATS:

- *Most habitats are described in terms of an 'ideal' which conforms to one or more classifications based on species composition*
- *Mosaics of habitats are often considered as sub-optimal*
- *Successional phases of many terrestrial or wetland habitats are discouraged by management*
- *Physical structure of habitats is not clearly covered in habitat definitions*
- *Few BAP priority habitats are managed for the transitional areas between them*

SPECIES:

- *Perceived incompatibility of habitat requirements between different species on similar habitats in the same location*
- *Overly prescriptive focus on a few species which may have very different requirements to more generalist species*

In addition, for both habitats and species, there is a tendency to focus on 'features' to the detriment of the wider system. Timescales for responses to management are poorly understood, often with time-lags between action and response. Another complication is the limitations of attempting to assign species to a distinctive habitat. There is a much wider range of rare or scarce species utilising habitats other than the BAP priority species. An ongoing coastal shingle habitat inventory project focused only on those 15 BAP priority species identified in the analysis in Webb et al (2010) which were associated solely with shingle. Data records for these species were included in the development of sample site studies. Some taxonomic specialists considered this was a limited range of the overall species that could be found on shingle, or transitions between shingle and other coastal habitats. Shingle, and transitions between shingle and other coastal habitats, are known to support important populations of a range of (non-BAP) rare/scarce or red-listed taxa, e.g. *Lathyrus japonicus, Sarcocornia perennis, Suaeda vera, Limonium bellidifolium, Hypochaeris glabra, Poa bulbosa, Silene conica, Petrorhagia nanteuilii, Polygonum maritimum* (S. Leach, pers comm.) The data incorporated into the site studies was therefore not the complete picture of the species' interests of that location. As a consequence, management advice may have a lower focus on those species and opportunities may be missed.

IV MANAGEMENT AND MONITORING OF TRANSITIONS

In the coastal environment in particular, the inherent dynamism of habitats as a result of coastal processes dictates that habitat management must be closely based on an understanding of these changes. This dynamism also means that in unmodified situations, there is a greater range of between and within habitat transitions, which may be cyclical rather than successional.

Natural England Managers of selected coastal National Nature Reserves (NNRs) were asked about their needs for guidance on management of transitions. In some cases, management does focus on the species of the transitional areas, for example invertebrates that require bare ground in the transition between embryonic and mobile dunes. Others reported that open habitat transitions arose inadvertently when creating pools by excavating sand for natterjack toads (*Epidalea calamita*). The bare areas were colonised by invertebrates and rare bryophytes. *Sueada vera* scrub, at the upper level of saltmarsh, was reported to be used by breeding passerines, reed bunting (*Emberiza schoeniclus*) and linnet (*Carduelis cannabina*), both BAP priority species, but not exclusively associated with coastal habitat. In most cases, the transitions were sustained naturally without intervention. Managers want guidance on the optimal level of intervention in coastal processes, or how human pressures can be effectively managed to limit damage to transitional zones. A further concern was how to monitor transitions: the inclusion of saltmarsh-dune transitions in monitoring units meant that sometimes they were included in an area that would be defined as 'saltmarsh' and in others as 'sand dune', but not effectively monitored as transitions. (M. Rooney, J. Walker, and S. Cooter, pers comms).

Successional transitions may also be considered as important for species, but which cannot be sustained in the same location from year to year in dynamic coastal systems. One example is the use of newly-created intertidal areas that have initially developed dense stands of *Salicornia* species. This habitat, which is a typical transitional zone between vegetated saltmarsh and bare mudflat, has recently been noted to support wintering twite (*Carduelis flavirostris*) (Badley and Allcorn 2006), and the question has been asked: can the system be 'held' artificially at this stage to promote high densities of *Salicornia* and other annuals for the birds to feed on? The implications for saltmarsh development could reduce the likelihood of achieving the full range of habitat targets, so it is important that the integration of habitat and species is done with a full understanding of both of their needs and the active coastal processes.

V COASTAL HABITATS AND SPECIES

A review of the habitat requirements of BAP priority species in England has been carried out to help inform the integration of species and habitat management (Webb et al 2010). For their size, coastal habitats support a high number of priority species compared to other habitats.

TABLE II. COASTAL HABITAT EXTENT AND ASSOCIATED BAP PRIORITY SPECIES IN ENGLAND (Webb et al 2010)

BAP Priority Habitat	Extent in England (ha) (from Natural England 2008)	Number of BAP Priority Species supported by habitat in England	Number of localised/restricted/very restricted species *
Saline lagoons	1649	12	10
Coastal vegetated shingle	4495	15	11
Coastal sand dunes	12,800	72	60
Maritime cliff and slope	14,545	61	53
Littoral sediment (saltmarsh and mudflat)	231,880	30	25
Totals	265,369	190	149

*** Explanation of distribution terms:**
Recorded from 1-5 sites - very restricted.
Recorded from up to 15 10km squares and over 1-5 sites - restricted.
Recorded from 16-100 10km squares - localised.
Recorded from over 100 10km squares - widespread

In comparison, broadleaved woodland habitats, with an approximate extent of 510,292ha in England, with 6 different BAP priority habitats, support 256 species. Coastal and floodplain grazing marsh has an extent of 235,046ha and is associated with 47 BAP priority species.

The evaluation of BAP priority species requirements (Webb et al 2010) carried out by Natural England indicates which habitat attributes are important for species (Table III). This analysis was carried out by habitat, so does not cover those species associated with transitions between habitats. This can help to identify what elements of transitional zones (bare ground, hydrology etc) could be important for species.

TABLE III SPECIES HABITAT REQUIREMENTS (From Webb at al 2010)

BAP Priority Habitat	Species' habitat requirements	Comments
Saline lagoons	Shelter from wave action; permanent water; exposed damp substrates	Salinity requirements are variable
Coastal vegetated shingle	Bare, naturally sorted shingle; ruderal herbs; low anthropogenic disturbance; presence of snails; extensive flower forage.	Snails are host species of snail-killing fly Salticella fasciata
Coastal sand dunes	Bare ground; dune slacks; scrub; mosaics (small-scale); shelter from wind	Hydrology and sand dynamics are important
Maritime Cliff and Slope	Open/bare ground; crevices; seepages; shelter; short-turf mosaic; scrub	Soft cliffs support a different range of species to hard cliffs
Saltmarsh	Bare mud; vegetation; open land; plant litter	60% of species make use of upper saltmarsh

Techniques for assessing the importance and characteristics of transitions within and between habitats for species also need to be established. This has not been addressed in the UK. One study in Italy investigated the patterns of biodiversity across a sand dune system (Acosta et al 2009). By sampling plant species across zones of a dune system, it was determined that although increasing stability towards the land was reflected in an increasing number of species, peaking in the intermediate dune, the more species-poor strandline habitats contained a greater proportion of rare species, with a high degree of restriction to that zone. One conclusion was that greater emphasis was needed on the complete coastal mosaic to conserve the wide range of biodiversity. Such analysis would be useful to apply in the UK across a range of transitional habitats between coastal and other systems.

In many coastal situations a mosaic of habitats may be present, interacting as a result of coastal processes over a range of timescales. In addition, transitions between habitats are also common, both between different coastal habitats and between coastal and other habitats. The importance of mosaics is recognised in the SSSI selection guidelines for coastal habitats (NCC 1989) which highlight that coastal sedimentary habitats may exhibit successional sequences, showing transitions to each other and non-maritime habitats. The selection of SSSIs should reflect this variation, with an emphasis on the geographic variation and sequential and transitional features being adequately represented in the SSSI series. The most important sites should therefore not only have habitats with a complete succession or zonation within the habitat, but also transitions to other terrestrial habitats. In such instances, even small sites with good examples of transitions, zonation or mosaics (described as 'ecotones' in the SSSI guidelines) could quality for SSSI selection if they were considered as the best example in an area of search, even though they may not necessarily meet the size thresholds for the individual habitats.

There are a range of different transition types, although these are not fully described in any formal way. Transitions can occur in designated sites, even though they may not in themselves be a qualifying feature, they can support species which are recognised as important.

Monitoring guidance for species can vary in the approach to habitats and transitions. The use of 'indirect' attributes relating to habitat condition are recommended for many species as well as direct population counts for invertebrates and plants (JNCC 2004b, 2008). It may not always be appropriate to simply use the targets that would apply to habitats, these would need to be modified to recognise that a habitat (or parts of it), in poor condition, may actually be beneficial for some species. Guidance for invertebrates (JNCC 2008) recognises the value of 'microhabitats', but only has limited explanation of what this means. For plants, there is a specific suite of guidance for vascular plants of disturbed/compacted coastal habitats (JNCC 2004b). Several of these species are identified in Table IV, and are particularly associated with coastal transitional habitats on sea walls or upper saltmarshes.

VI COASTAL TRANSITIONS IN ENGLAND

Figure 1. Map showing locations described in the paper

Many coastlines in England have been modified by a range of activities, which affects the way in which they function and interact. Coastal flood risk management in particular has affected many stretches of low-lying sedimentary coastlines. It is estimated that 55% of the English coastline is protected by defences from flooding (EC 2004). In Essex, for example, there are 3376ha of saltmarsh (approximately 10% of the UK resource), (English Nature 2000), but only three small frontages where there is a natural transition at the upper limit of tidal inundation. The long-term sustainability of current flood risk management for this complex of Natura 2000 sites was investigated as part of the Living with the Sea LIFE project (http://www.eclife.naturalengland.org.uk/about_the_project/default.asp). From this project, the Essex Coastal Habitat Management Plan (CHaMP), (Posford Haskoning 2003), highlighted the need to restore brackish-freshwater transitions in the long-term through managed realignment to rising ground or by allowing seepage through embankments.

This issue of loss of the interface between habitats was also identified by the ELOISE project, also an EU-funded study, (http://www.eloisegroup.org/themes/habitats/contents.htm) which reviewed the knowledge base for habitat dynamics at the coast-catchment interface. Two types of dynamics, those within habitats and those between habitats, were addressed. This work included case studies of the Humber Estuary and managed realignment of sea defences to sustain the estuary and its habitats. One issue identified was that the natural succession of marine to terrestrial environments has been truncated by the construction of seawalls. Before extensive human involvement the vegetation succession probably incorporated much wider tracts of saltmarsh, progressing to less saline fen and carr environments, it now ends at mature saltmarsh. These types of marginal marine-terrestrial environments are no longer present in the Humber system. The conclusions of the work indicated a need for improving European-wide understanding of coastal habitat dynamics.

In contrast, there are sites on the north west coast of England that have extensive natural transitions, absent in most other British estuaries, for example the Drigg coast in Cumbria.
http://www.jncc.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0013031

The estuary complex here is designated as a Special Area of Conservation (SAC) for 10 Annex I habitat types, from saltmarsh to dune slacks, and is one of the most natural and least developed in the UK, with little industry and virtually no artificial coastal defences. It contains some of the best examples of undisturbed transitions to freshwater and sand dune habitats of any estuary in the UK. The estuary complex covers approximately 11kms of coastal frontage. Within this

1413ha site there is an excellent zonation of saltmarsh habitats from pioneer through to upper marsh and some of the least disturbed transitions to terrestrial habitats, particularly to sand dune, shingle and freshwater swamp.

Figure 2. Point of Ayr, Wales. A range of coastal transitions illustrate the complex mosaics of habitats, with transitions between shingle, sand dunes and intertidal habitats in an active coastal system. Copyright Angus Garbutt 2010.

VII SALTMARSH TO GRASSLAND TRANSITIONS

In the UK transitions between saltmarsh and several other habitats are present; salt marsh to:

- *shingle,*
- *sand dune,*
- *reed swamp and fen,*
- *bog,*
- *woodland,*
- *terrestrial grassland*
- *coastal embankments.*

Transitions occur across salinity gradients along estuaries and across elevational gradients from intertidal to terrestrial environments. Transitional zones across both type of gradient are uncommon in England as a result of channel modification and embankment for flood defence.

Intertidal ecosystems are subject to periodic disturbance. For mudflats and salt marshes the major 'disturbance event' is tidal flooding which is regular and predictable and creates a characteristic zonation of plant assemblages (Adam 1990). Towards the upper edge of salt marshes disturbance by tidal flooding is infrequent and unpredictable, usually driven by storm events and coinciding with high tides. Disturbance in this transitional zone between the intertidal and terrestrial or freshwater environment creates gaps, or niches, in what would otherwise be a closed vegetation community. Gaps are created by either physical disturbance such as the erosion of soil or vegetation, the deposition of sediment or tidal litter, or by an increase in salinity which kills off non-salt tolerant plants or creates hyper-saline conditions in marginal pools (Gray 1989). Left undisturbed, these transition zones would become dominated by perennial grasses and shrubs. In order to gain an understanding of the maintenance of saltmarsh to grassland transition zones, Gray (1998) categorised saltmarsh 'coastal fringe' plant species by their life history characteristics (Figure 1). In contrast to the saltmarsh, where 90% of species had perennial life histories, 70% of coastal fringe species were annuals or of an indeterminate or short lived life history. The only widespread and commonly occurring annual species in saltmarsh are *Salicornia* species and *Suaeda maritima*. These species are characteristic of the mudflat transition zone where tolerance to high inundation frequency and salinity are required for recruitment and survival.

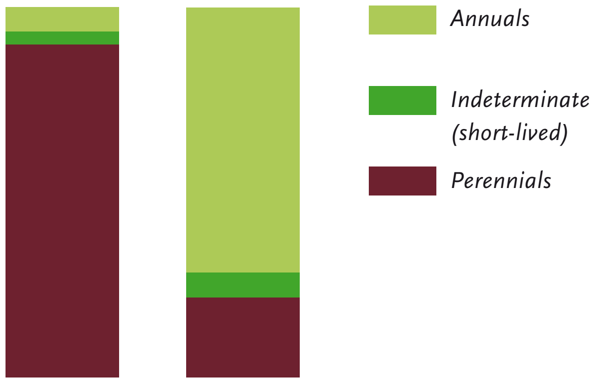

Figure 2. Life history characteristics of flowering plants from British salt marshes and transition zones (between mean high water spring tides and extreme high water). Adapted from Gray 1998.

Many species characteristic of the upper saltmarsh transition zone also have annual life histories. Species such as *Puccinellia rupestris, Bupleurum tenuissimum, Trifolium squamosum, Peucedanum officinale, Hordeum maritimum* all occur in a narrow zone between the upper limits of saltmarsh and neutral grassland, or in areas of saline seepage behind coastal defences (Table IV).

This is a suite of nationally and locally scarce species which are found on upper saltmarsh transitions to damp grassland and on coastal grazing marsh (grazing land created from saltmarsh by excluding tidal incursion by building sea walls). In grazing marsh habitat, the presence of these species may indicate the past existence of a more natural transition. However, as most of the enclosure of low-lying areas has been carried out historically, there are few natural examples remaining of extensive saltmarsh-grassland transitions. Many of the sites which retained elements of this transition have since been modified by agriculture. Unmodified systems can still retain the topography of old saltmarsh creeks, and in some places the ditches can still have a brackish character.

TABLE IV SPECIES ASSOCIATED WITH SALTMARSH AND COASTAL GRAZING MARSH TRANSITIONS

Data source: [1]Maplin grazing marsh study (Macey 1974); [2]Severn Estuary saltmarsh survey (Dargie 1998); [3]Ramsar interest feature of feature of Colne and/or Blackwater Estuaries, Essex; [4]Priority BAP species linked to saltmarsh habitat. **Rarity status:** see Table II explanation of distribution terms.

Species	Rarity status	Life history	Habitat preference
Puccinellia rupestris [1,2]	Localised	annual	Upper salt marsh, bare ground, vehicle tracks, cattle poached mud behind sea walls
Puccinellia distans [1]	Widespread	perennial	Upper salt marsh
Puccinellia fasciculata [1,2,3,4]	Localised	perennial	Bare ground cattle poached mud
Bupleurum tenuissimum [1,2,4]	Localised	annual	Disturbed ground on sea walls, upper salt marshes
Trifolium squamosum [1,2]	Localised	annual	Upper salt marshes and brackish meadows, behind sea walls in areas of saline seepage
Peucedanum officinale [1]	Very restricted	perennial	Coastal grassland on, or behind sea walls and brackish marsh
Hordeum marinum [1,2,3,4]	Localised	annual	Upper salt marsh, bare ground near the sea
Bolboschoenus maritimus [1]	Localised	perennial	Brackish upper reaches of estuaries or ditches behind sea walls
Polypogon monspeliensis [1]	Localised	annual	Bare or sparsely grassy ground by the coast
Ranunculus baudotii [1,3]	Widespread	annual	Brackish ditches by the sea
Parapholis strigosa [1]	Widespread	annual	Upper salt marshes and bare ground near the sea

A 1970s vegetation study of the North Kent Marshes (Macey 1974) attempted to understand the changes following saltmarsh reclamation and the factors that influenced it. At that time, most of the reclaimed marshes were still unimproved and still supported a wide range of these plant species, several of which are nationally scarce.

Key factors influencing species presence identified in the 1974 study were soil moisture, salinity and management. Different combinations of factors altered the combinations of species present. Overall, the reclaimed marsh habitat was considered to include both the landward and seaward areas of the sea wall.

High species density was recorded on the landward sides of the sea wall, which would have had some commonalities with the high level saltmarsh habitat, and may be influenced by grazing. Recently, the Joint Nature Conservation Committee (JNCC) has developed generic management recommendations for BAP priority species. For Bupleurum tenuissimum this includes two key elements that are linked to coastal management:

- *'Ensure appropriate habitat condition at sites including maintaining open areas and increasing grazing and poaching by cattle or sheep to help control main competitors e.g. Elytrigia atherica' and;*
- *'Ensure needs of this species are taken into account when devising coastal defence strategies, including managed retreat/re-alignment (including Shoreline Management Plans). Ensure measures are incorporated into Local Plans and Structure Plans to prevent further losses of its saline/brackish habitats (saltmarsh and grazing marsh), either to development or agricultural intensification (e.g. conversion to arable).'*

For the first action, there is potential conflict with the management of the sward to maintain the overall vegetation community, where extensive bare ground is considered detrimental. In order to be considered to be in 'favourable condition', saltmarsh habitat should have less than 25% bare ground as a result of poaching damage by livestock (JNCC 2004), whereas condition assessment for the vascular plants listed in Table IV requires more than 20% bare ground within the zone they are associated with.

VIII RE-CREATION OF TRANSITIONAL COMMUNITIES

In the United Kingdom, coastal defence has been the primary objective of intertidal habitat restoration (Wolters et al 2005). Rising sea levels, coupled with the high cost of maintaining coastal defences, have led coastal managers to look for more cost effective and sustainable methods of coastal protection. Managed realignment, the landward retreat of coastal defences and subsequent tidal inundation of reclaimed land has, since the early 1990s, been increasingly used to fulfil these requirements. Broadly speaking managed realignment schemes in the UK have shown that with relatively minimal pre-treatment and/or management of the area, allowing tidal ingress through a simple, relatively small breach of the existing sea wall, onto low-lying agricultural land will quickly produce intertidal mudflats which are colonised by salt marsh plants (Garbutt et al 2006). Evidence to date has shown that managed realignment sites are sinks of sediment and, given time and the appropriate elevation, recognisable plant communities can develop. At sites where the land surface rises up to, or beyond, highest astronomical tide (HAT) saltmarsh to grassland transition communities have developed.

Figure 3. Tollesbury managed realignment site, Essex. The initial breach in 1995 showing the first seawater entering the site. Copyright Carol Reid 1995

There are several managed realignment sites in England that have unimpeded transition zones to terrestrial grassland (e.g. Hesketh Outmarsh in Lancashire, Paull Holme Strays on the Humber in East Yorkshire, Orplands and Abbotts Hall, both in Essex). The site at Abbotts Hall on the Blackwater Estuary in Essex has the longest restored tidal/terrestrial transition zone in the UK. Created in 2002, the coastal defences at the site were breached in five places along a 3km length of coastline allowing tidal flooding of 50ha of reclaimed farmland. At the upper limits of tidal inundation, 35ha of terrestrial grassland were created on formerly cultivated arable fields. The intertidal areas and intervening transition zone were allowed to colonise naturally by plants and animals. Saltmarsh plants rapidly colonised the lower areas of the site. The transition zone developed a ruderal plant community dominated by *Cirsium arvense, Brassica nigra, Sisymbrium officianle* and *Picris echioides*. In addition to the natural colonisation of the transition zone, *Peucedanum officinale* seeds and plug plants were introduced from 2003/04 (Essex Biodiversity Project 2004). The plant is rare to Britain, occurring in three isolated coastal populations, locally to the Abbotts Hall site. The plant also supports two rare moth species (*Gortyna borelii lunata* and *Agonopterix putridella*). While the establishment of *Peucedanum officinale* by plug plants proved relatively successful, the plant community of the transition zone continues to be dominated by ruderal species rather than a more grass dominated sward typical of the region.

The plant community of the Abbotts Hall transition zone contrasts with that of two other managed realignment sites in the region; Orplands (created in 1995), also on the Blackwater estuary and Brandy Hole (created in 2002) on the Croach estuary in Essex just to the south. The plant communities of these sites have developed characteristic, grass dominated transition zones. At the Orplands site, upper salt marsh merges into *Elytrigia atherica* and *Agrostis stolonifera* dominated grassland with characteristic species of coastal inundation grassland such as *Festuca arundinacea, Potentilla anserina, Trifolium repens, Carex otrubae, Odontites verna* and discrete stands of *Atriplex portulacoides*. A similar community and one dominated by *Elytrigia atherica* is represented at the Brandy Hole site. Why the communities of the Orplands and Brandy Hole sites differ to Abbotts Hall is unclear. Pre-inundation land use was agricultural in each case, although the time scales since reclamation differ. One obvious difference is the gradient of the slope through the transition zone, which is far greater at Abbotts Hall than the other two sites. The steepness of the slope reduced the transition zone at Abbotts Hall to a few metres in width compared to a much more extensive zone at the other sites.

More attention needs to be given to the requirements of transition zones in the design of managed realignment schemes by identifying relevant physical elements, suitable populations nearby for transfer of propagules as well as artificial introduction of species. Understanding of how habitats develop naturally, and the types of timescales involved, could help with designing and managing habitat creation projects that promote development of transitions.

IX NATURAL DEVELOPMENT OF TRANSITIONAL HABITATS

BIRKDALE GREEN BEACH

In the UK one of the most exciting areas of rapidly developing transition habitat is known as the Birkdale Green Beach on the Sefton Coast in north west England. Smith (2007) describes how, over a period of 20 years, a 62ha mosaic of sand-

Figure 4. Birkdale Green Beach, Sefton Coast, North West England.Copyright: North West and North Wales Coastal Group 2010

dune, dune-slack, high level saltmarsh and swamp communities developed along a 4km dune frontage. The green beach zone is up to 200m wide and continues to grow. The development of the green beach began in 1986 as scattered patches of *Puccinellia maritima* on the open beach about 100m from the dune edge. Edmondson et al. (1991) in a study of vegetation types concluded that 'the process of development is clearly transitional from saltmarsh to sand dune'.

Although *Puccinellia maritima* is more commonly associated with the pioneer stage of salt-marsh development, on the Birkdale Green Beach it was the precursor to the development of dune hummocks. *Puccinellia* is not just responding to an increased beach level, it also has the capacity to accelerate sediment accumulation. In a study in Mont Saint-Michel Bay, Langlois et al. (2003) showed that the presence of *Puccinellia* appeared to be strongly linked to the development of hummocks and a micro-topography.

The number of plant species associated with the Birkdale Green Beach increased from 2 in 1986 to 269 in 2007 (Smith 2007). Along with species associated with strandline, sand dune and primary slacks, there are several that colonise the transition between maritime and freshwater conditions. These include parsley water-dropwort *Oenanthe lachenalii*, long-bracted sedge *Carex distans*, frog rush *Juncus ambiguous*, lesser water-parsnip *Berula erecta* and wild celery *Apium graveolum*. The young primary slack zone is also an important habitat for the rare thread-mosses *Bryum dyffrynense* and *B. warneum* (Smith 2007).

The young habitat of the Green Beach is also rich in invertebrates including some associated with transition zones. These include the short-winged conehead *Conocephalus dorsalis* associated with maritime rushes and grasses on saltmarshes and sand dunes and found in patches of sea club-rush *Bolboschoenus maritimus* and the sandhill rustic moth *Luperina nickerlii* spp. *gueneei* normally associated with sand couch *Elytrigia juncea*, but also found at Birkdale on common saltmarsh grass. Sites such as the Birkdale Green Beach are extremely important for study as they can also be a window into past changes. Coastal processes in this part of the coast have created conditions perhaps not seen for a century. For example, the hybrid sedge *Carex x pseudoaxillaris* which was found on the Birkdale Green Beach in 2006 had not been recorded on the Sefton Coast since the 1890s.

The transition between salt marsh and sand dune, and the development of new primary slack communities, is an ideal habitat for the natterjack toad *Epidalea calamita*. Natterjack toad colonised the Green Beach in 2001 and from 2005 one of the largest sub-populations on the Sefton Coast has developed with 218 spawn strings counted in 2007. The habitat is ideal for natterjack toads as tidal inundation around the spring equinox eliminates the competitive common toad *Bufo bufo* tadpoles before the natterjack toads spawn. Water levels are maintained in the spring through runoff from the dunes and freshwater drains.

THE NORTH NORFOLK COAST

This barrier beach coastline of eastern England is one of the most dynamic coasts in Europe, exhibiting a range of soft coastal landforms from shingle barriers, to tidal creeks and sand dunes. (http://www.esfjc.co.uk/ems/pages/ems.htm). Blakeney Point and Scolt Head Island are two well studied coastal sites (Allison and Morley 1989). One particular interesting transition at Blakeney Point is that between sand dunes and shingle. Where the shingle base is exposed by wind or tidal inundation, landscape features known as 'lows' are formed. These slack-like habitats are normally fed from fresh water but also can be flooded by sea water at irregular intervals. Because only the highest tides will flood the lows, the water can remain for days or weeks before it drains away (White 1989).

Also on Blakeney Point are depressions in the shingle landforms which allow sea water incursion on more regular intervals. As with the 'lows' in the dune landscape the sea water may take some time to drain away. This creates an interesting vegetation with abundant shrubby seablite *Suaeda vera*, sea plantain *Plantago maritima*, matted sea-lavender *Limonium bellidifolium*, and sea-heath *Frankenia laevis* (White 1989). These transitions are also seen on Scolt Head Island (Woodell 1989) where there is a range of plant communities grading from saltmarsh to lichen-rich shingle communities similar to dry dunes.

In such transition habitats even the activity of rabbits or ants can make a significant difference to the colonisation and survival of plants. Woodell (1989) shows how concentrations of rabbit droppings on the shingle provides a niche for species such as thrift *Armeria maritima* and biting stonecrop *Sedum acre*, the rabbit droppings providing the fertiliser in what is otherwise a hostile environment. Ants can also affect the local environment. Woodell (1989) describes how ants of the genus *Lasius* can form small anthills near the upper saltmarsh providing another niche for plants. He calls the anthills 'aspect mounds' for he could show that *Frankenia laevis* colonises these mounds and is more abundant on the south side. This example indicates the complex relationships between species that can be found in transitional areas. In many cases it is the management of the transitional habitat for individual species or assemblages that requires further development.

X SPECIES MANAGEMENT IN TRANSITIONAL AREAS

For invertebrates there is an increasing body of information about management of habitats for species. Some recent work by Buglife, funded by Defra, gives advice on management for 32 BAP priority habitats.
http://www.buglife.org.uk/conservation/adviceonmanagingbaphabitats [accessed June 2010].These give good examples of explaining the importance of transitions for invertebrates and how management objectives should sustain these. The following examples also describe some recent developments in understanding for two invertebrates and one amphibian.

VERTIGO ANGUSTIOR

The c. 2mm narrow-mouthed whorl snail *Vertigo angustior* is listed in Annex II of the Habitats Directive which is known from the transition zone between saltmarsh and wet grassland. In Suffolk, for example, it inhabits a narrow transition zone (c. 10 m wide) just above the saltmarsh and tidal drift-line at Martlesham Creek on the Deben Estuary (see http://www.suffolk.gov.uk/Environment/Biodiversity). The species may be threatened at this site by the development of tall reed canary-grass *Phalaris arundinacea* vegetation which shades out an *Iris/Carex* community. In addition, there is concern about the impact of coastal squeeze on the sustainability of populations, especially those that have only been recently found (D Heaver, pers comm.).

The species was also found at Whiteford Burrows in Wales in 1983 and is confined to a narrow band within the dune-saltmarsh transition where it is locally abundant. It is considered to be one of the strongest populations in Europe (Fowles and Guest 2006). The transition habitat is described as a yellow iris *Iris pseudacorus* dominated marsh, where freshwater seepages are inundated by sea water on the highest spring tides (Fowles and Guest 2006). The preferred habitat of *Vertigo angustior* is intermediate between dry dune grassland and wetter parts of the saltmarsh. The highest densities (c. 1200 snails per square metre) of the species are associated with herb-rich grassland with fine-leaved grasses, especially red fescue *Festuca rubra*, and particularly where there is a persistent litter layer.

The management of the transition zone is aimed at maintaining the favourable condition of this species. Fowles and Guest (2006) reported that the distribution of *Vertigo angustior* at Whiteford Burrows was influenced by the groundwater level, grazing pressure from ponies on the saltmarsh and periodic flooding by high tides. The main management issue was in relation to variations in vegetation succession in response to grazing pressures. Ponies, owned by commoners, preferentially graze the saltmarsh transition zone and help maintain the habitat. The grazing pressure is not considered to be detrimental to uncommon plant species, including sharp rush *Juncus acutus* and marsh mallow *Althaea officinalis*. There are concerns that if grazing pressure is reduced the area will become invaded by common reed *Phragmites australis*, alder *Alnus glutinosa* and sea rush *Juncus maritimus*.

This experience needs to be shared across the UK.

SANDHILL RUSTIC MOTH

The sandhill rustic moth *Luperina nickerlii* occurs in three subspecies in England (Spalding 2002). All are associated with coastal habitats which experience some tidal inundation. The larvae of ssp. *gueneei* and *leechi* feed on sand couch *Elytrigia juncea* and of spp. *demuthi* on common saltmarsh grass *Puccinellia maritima*. Spalding (2002) suggests that habitats may include maritime cliff with red fescue *Festuca rubra*, sand dune and shingle beach with sand couch grass and saltmarsh with common saltmarsh grass.

The sub species *gueneei* is found in north west England and north Wales. It is known from sites with sand couch which is occasionally washed by sea water. In 2007 a survey of the species by the Lancashire Moth Group found several individuals on common saltmarsh grass on the Birkdale Green Beach. This behaviour has only been recorded previously for subspecies *demuthi* in Essex and Kent on the other side of the country.

NATTERJACK TOAD

The natterjack toad is found in both sand dune and saltmarsh habitats and even in shingle-sand dune transitions. It is not confined to transition habitats, but can exploit these habitats to its advantage. A particularly good example of the use of these habitats comes from the population in Cumbria, in North West England (Banks 1997). At the Haverigg Dunes site one of the main breeding pools is found where the dunes meet a shingle ridge. Although the pools are inundated with sea water in the winter and early spring, the freshwater runoff from the dunes creates freshwater conditions in the breeding period. The natural dynamism of this dune/shingle coast should ensure a constant supply of similar pools (Banks 1997).

Coastal ponds subject to occasional inundation are a key breeding habitat for the natterjack toad (Banks 1997). In 1997, 16 of a total of 23 breeding sites in Cumbria were in pools subject to some tidal inundation. At several dune systems it is the saltmarsh breeding pools which provide the best recruitment to the populations which are associated with the sand dune habitat. Several saltmarsh breeding pools, however, are not associated with sand dunes; the key factors supporting the natterjack toad populations appear to be grazing (maintaining short vegetation) and freshwater flushing at the top of the marsh. Unlike freshwater pools, breeding pools on saltmarshes do not need to be ephemeral as the saline conditions for part of the year help to remove predators and competitors.

XI CONCLUSIONS AND RECOMMENDATIONS

This review of coastal habitat transitions and their relevance to species has highlighted their importance for the conservation of species. Understanding more about the management needs for both habitats and species is essential if integration of management actions is to be successful and lead to improvements in the status of BAP priority species. With climate change likely to impact on the coast and processes that sustain it, there needs to be a much wider view taken of how coastal and terrestrial habitats interact to enable effective adaptive management. A critical issue is to ensure that planned management can be adjusted as predictions for climate change impacts become a reality. The transitional habitats between coastal and terrestrial/wetland zones may become more important as refuges for some species, but unless managers recognise their importance, resources are likely to become most focused on the more 'typical' habitats.

There are several issues that need to be addressed:

- *Greater consistency in identification and description of transitional zones*
- *Closer working between species and habitat specialists, as well as between different habitat specialists*
- *Better understanding of the physical processes that influence the development and quality of transitions, such as hydrology, macro- and micro-topography, sediment type, sediment movement and climate in order to understand whether management interventions are necessary and if so to what degree*
- *Learning from Nature by applying understanding of coastal transitions to other habitat types: the Birkdale Green Beach was naturally colonised by several unusual species – where did these species come from and how did they arrive?*
- *Designing habitat creation schemes, particularly managed realignment, to enable the development and maintenance of transitions without the need for excessive intervention*
- *Understanding of the vulnerability of transitions to human pressures: because they are often 'overlooked' as not fitting into standard classifications, their needs, and those of the associated species, may not be fully addressed*
- *More effective linkage in monitoring programmes to ensure that the condition of transitional habitats and species is properly reported.*

For the development of Integrated Biodiversity Delivery Area objectives and working at a landscape scale, it will be essential to have good information about the distribution and extent of habitats, species and the connectivity within the landscape. It will also require partnerships to have clearly shared interests and a range of experience.

It will be essential to develop management guidance. Although there is a wealth of good information on management of individual species and habitats, this is not integrated, so good signposting is needed to derive the greatest benefits and avoid conflicts between priorities. If projects are at a large enough scale, there should be opportunities to focus on one or both elements.

The coastal zone is going to be a relatively small spatial element of IBDAs, however because of the relatively high number of species supported by coastal habitats and associated transitions, the right management (which could include minimal intervention) could deliver multiple benefits.

Figure 5. At Brancaster, North Norfolk, removal of rock armour on sand dune frontage led to restoration of dune and saltmarsh function as part of the Living with the Sea LIFE project in 2002. Copyright Angus Garbutt

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