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



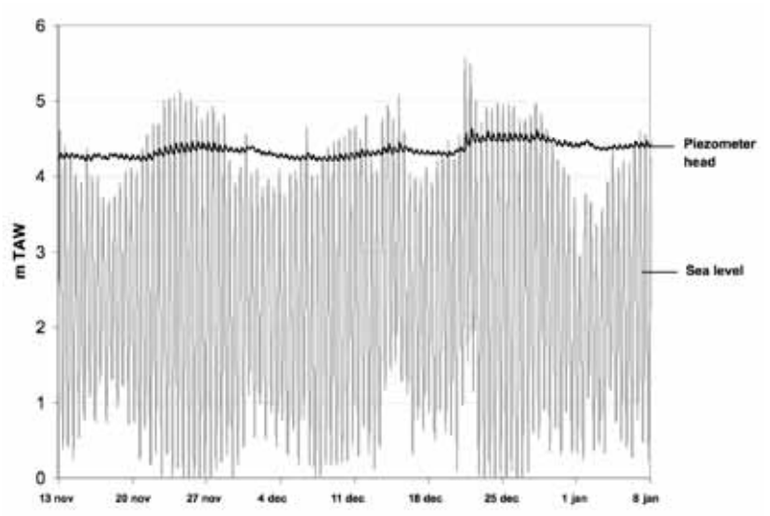


*Figure 4. Groundwater levels and fluctuations at the dune-beach transition in Nieuwpoort-IJzermonding (2003-'04).*

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.

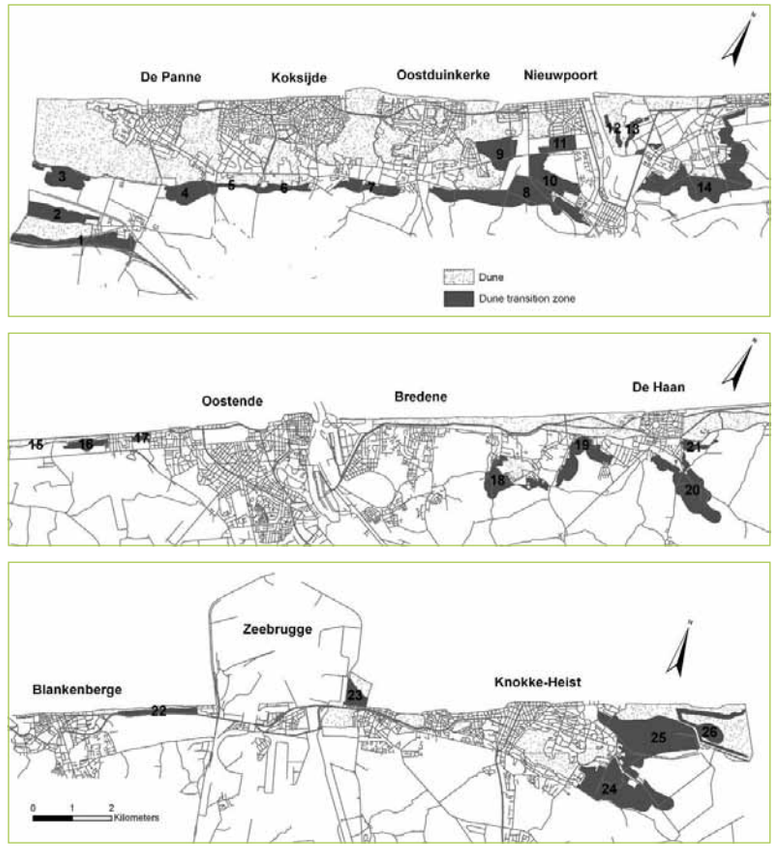


*Figure 6. Location of dune areas and transition zones along the Belgian coast.*

# 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.*
- *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.*

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

**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


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

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*).

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.

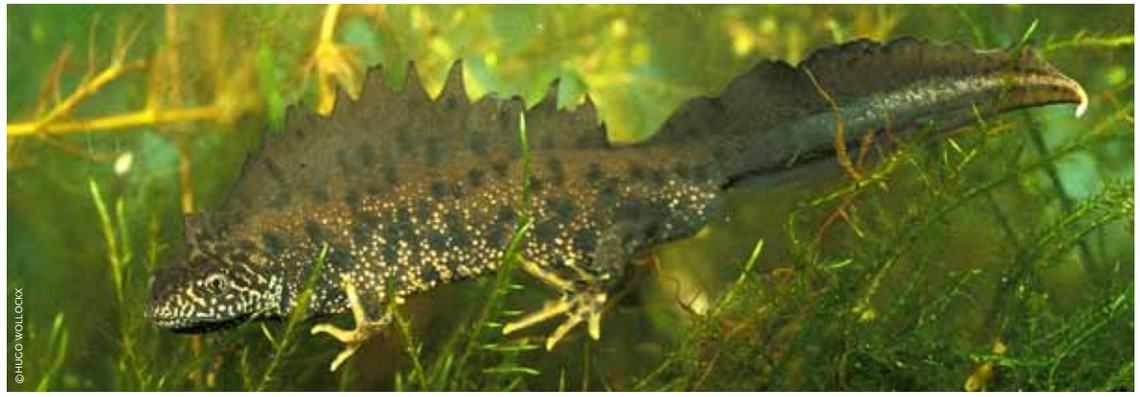


*Figure 27. Triturus cristatus*

**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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