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Integrated monitoring of nature restoration along ecotones, the example of the Yser Estuary

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Abstract

Within the framework of LIFE, one of the larger nature restoration projects in Flanders was realized on the right bank of the estuarine part of the Yser. General aim of the initiative was to restore or create beach-dune-salt marsh ecotones with salt-fresh, dynamic-stable, wet-dry and mud-sand ecotones. In order to reach this goal, several large buildings and roads were broken down, an entire tidal dock was restructured and some 500,000m³ of dredging material was removed to restore or create intertidal and coastal dune habitats and their connecting ecotones. Measures were taken to avoid abrupt topographical transitions along potential ecological gradients. It was decided to begin monitoring (2001-2004) from the very start of the restoration process (1999-2003). Monitoring was multidisciplinary and realized in a partnership between several scientific institutes (Ghent University, Catholic University of Louvain, Royal Belgian Institute of Natural Sciences and Institute of Nature Conservation with facility support of VLIZ). Monitoring included the most relevant abiotic conditions such as sedimentation and erosion, topography and ground water fluctuations, and biological response variables, *i.e.* flora and vegetation, terrestrial arthropods, benthic macrofauna and birds. It was decided to include two monitoring levels, an area-covering monitoring of the entire nature reserve (ca. 128ha) and a detailed monitoring of changes along transects perpendicular to the main ecological gradients. In this paper we present some results of the first three years of monitoring.

Keywords: Nature restoration; Monitoring; Estuary; Coastal dune; Ecotone.

Introduction

In a society where everything seems to focus on costs and benefits, it is vital that costs are evaluated quantitatively on their benefits and that preconceived goals are followed up on their extent of compliance. Therefore monitoring has become increasingly important, not in the least when dealing with the evaluation of result commitments made in nature conservation policy. Monitoring is defined as the intermittent (regular or irregular) surveillance carried out in order to ascertain the distance-to-target from a predetermined standard or the degree of deviation from an expected norm (Hellawell, 1991). Surveillance in this definition is referred to as an extended programme of surveys, undertaken in order to provide a time series, to ascertain the variability and/or range of states or values which might be encountered over time. In short, monitoring needs predefined goals, strictly defined standards, well-designed methods, rigorous follow-up in time and is meant to finally evaluate the distance-to-target from predefined goals.

A general problem of monitoring is finding the right sampling method to detect all relevant changes. When certain management measures need to be evaluated, it is important to be able to make the difference between management dependent and independent changes. Although several attempts have been made to design general monitoring schemes (*e.g.* Goldsmith, 1991; Van Olmen *et al.*, 2000; Van Dyck *et al.*, 2001; Demeulenaere *et al.,* 2002), every combination of predefined goals and hence every site has got its specific characteristics and needs therefore a specific, but standardized approach (*e.g.* Bonte *et al.,* 2001; Provoost *et al.,* 2004). Here we report on the approach used in a nature restoration project along the Yser Estuary at the Flemish coast.

Within the framework of LIFE, one of the larger nature restoration projects in Flanders was realized on the right bank of the estuarine Yser (Hoffmann, 2004). Restoration goals were a priori defined in an ecological target vision (Hoffmann *et al.,* 1996) and departed from the generally accepted thesis that areas rich in ecotones are potentially important hot spots of biological diversity, both at large scale (Schilthuizen, 2000; Smith *et al.,* 2001) at regional (*e.g.* Ward *et al.,* 1999) as at local scale (van Leeuwen, 1966). General aim of the initiative was to restore or create beach-dune-salt marsh ecotones with salt-fresh, dynamic-stable, wet-dry, mud-sand transitions and other biologically interfering gradients. Although beach-fore dune ecotones are an important part of the project, we here focus on the estuary-inner dune ecotones.

Methods

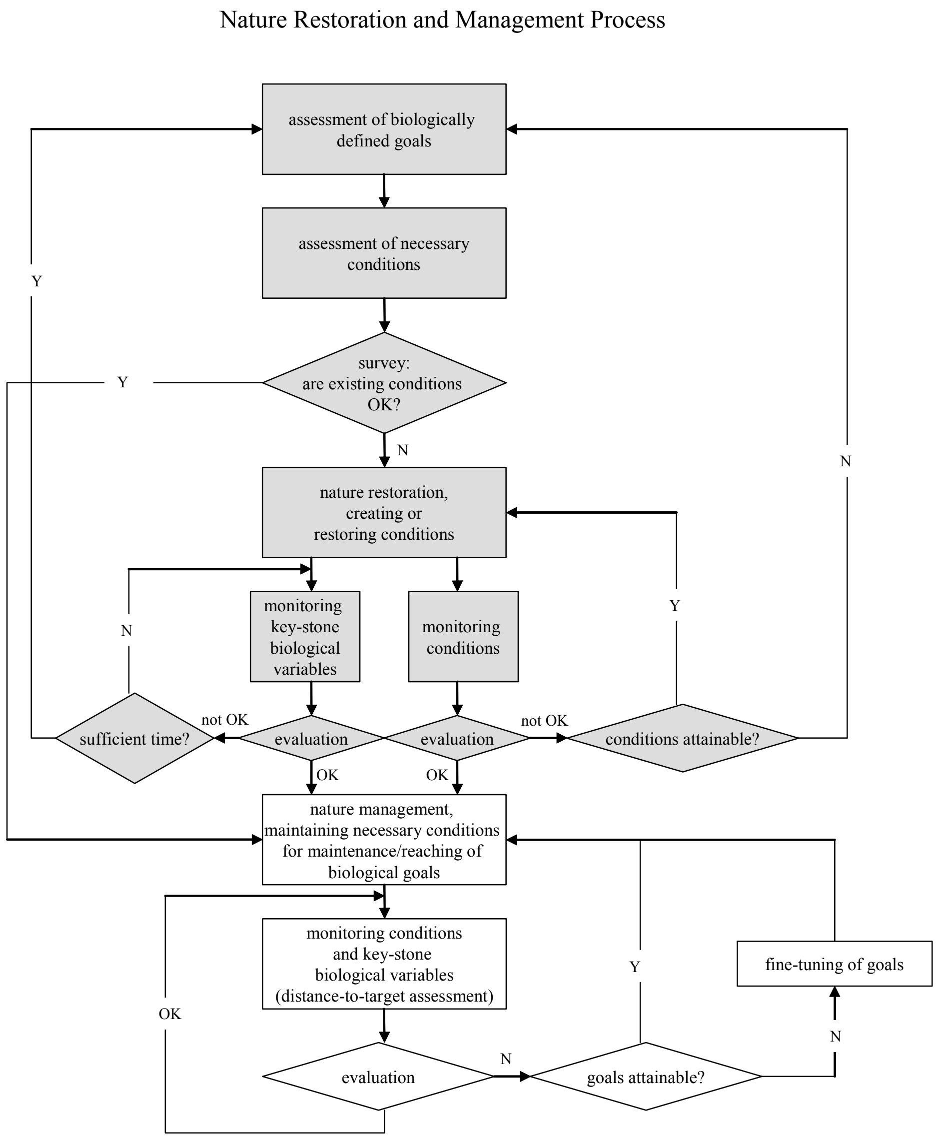

Fig. 1. General scheme of a nature restoration and management process. Steps that are dealt with in the restoration project at the Yser Estuary until 2004 are given in grey. Note that there is no end to the process and that monitoring is considered to be an inextricable part of it.

The nature restoration and management process at the Yser Estuary follows the generally applicable scheme given in Fig. 1. Hereafter, we will consecutively follow the different steps of the monitoring process, starting with the assessment of biological goals, followed by the assessment of necessary conditions, the survey of the existing conditions with a simultaneous survey of biological key-stone variables, immediately followed by monitoring of both, and finally a first evaluation of the survey result. The restoration process started in September 1999, the last large-scale measures were taken in spring 2003 (Herrier *et al.,* 2005). The monitoring programme started in the summer of 2001.

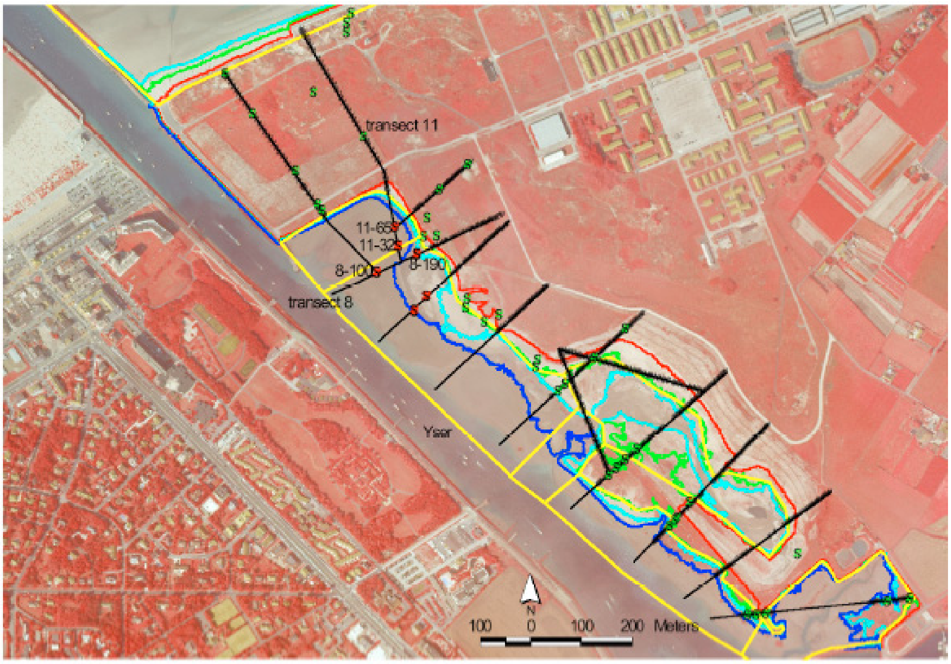

Fig. 2. False Colour Infrared aerial photograph of the nature restoration area in the Flemish Nature Reserve the IJzermonding, 29 July 2004. Monitoring transects and sampling points are indicated; black lines and circles: vegetation transects with permanent plots; green dots: invertebrate sampling sites; yellow polygons: areas distinguished for macrobenthos monitoring; red dots: permanent SE-plots; avifauna monitoring polygons are not given. Curved lines are tidal means (tide data from the period 1991-2000; Fremout, 2002), with topography based on the LIDAR-DEM (18 December 2002); dark blue: Mean Neap Tide High Water (MHWN); light blue: Mean High Water (MHW); green: Mean Spring Tide High Water (MHWS); red: Highest High Water (HHW).

Assessment of biologically defined goals

After several preliminary reports (Decleer and Meire, 1992; Bossu, 1993; Herrier, 1994), a definite ecological target vision was developed in 1996 (Hoffmann *et al.,* 1996). The general goal of the nature restoration project was to restore or create typical ecotones between beach, coastal dunes and estuary without further deterministic biological goals. These transitions should be as close as possible to the situation before dominance of human impact. Reference was obtained through interpretation of topographic maps from the 18th and 19th century. However, when aiming at ecotone restoration, a paradox occurred immediately, since monitoring needs clearly defined goals that can be measured and evaluated in distance-to-target figures. They are often defined as particular habitats or plant communities, which are considered as discontinuous entities. This contrasts with the goal to restore continuous ecotones. Based on the ecosystem vision of the Flemish coast (Provoost and Hoffmann, 1996), certain ecotopes per ecotone could be expected. Per ecotope several target habitats could be distinguished. Within the ecotope 'fore dune', target habitats were mobile open dune and calciphilous moss-dominated grey dune. Within the ecotope stabilized dune, target habitats were dry moss-dominated grey dunes, calciphilous grassland and coastal scrub. In the intertidal ecotope, target habitats were tidal gullies, mudflats, salt marsh, floodmark vegetation, young and open dunes. All of these target habitats can be evaluated on abiotic conditions as well as biological responders.

Assessment of necessary conditions

Necessary conditions for the development of the aspired ecotones are multiple. Basically though, they can be reduced to a small number of primary prerequisites: 1) Tidal movement of silt-loaded salt water in an only moderately dynamic environment, allowing a certain degree of sedimentation. This will allow spontaneous and natural development of salt marshes if condition five is met with; 2) Sand supply from the sea and aeolic sand transport is necessary for the development of new coastal sand dunes. However, since the main goal of the nature restoration process was to enlarge the intertidal salt marsh and mud flat area, bordering an *existing* dune landscape, marine and subsequent aeolic sand transport are not absolutely necessary to meet the biological goals, although the naturalness would greatly enhance when both processes would be in action; 3) Ground water conditions are vital for the development of different dune habitats and, to a minor extent to intertidal habitats (Criel *et al.,* 1999), reason why also ground water fluctuations and quality (conductivity) were investigated; 4) Topography is an indirect abiotic condition, *e.g.* dictating the annual inundation frequency of intertidal areas. Only sedimentation and erosion and topography are dealt with here.
Often overlooked but at least as important as abiotic conditions, is 5) Presence of diaspores of the organisms that are aspired to appear along the created or restored ecotones. This condition is becoming increasingly important in nature restoration projects that are realized in a highly fragmented landscape. Within the scope of this monitoring project, only the presence of angiosperm diaspores was studied (see Bossuyt *et al.,* 2005).

Creating or restoring conditions

The process of nature restoration is being dealt with in this volume by Herrier *et al.* (2005) [more details are given in Hoffmann (2004)].

Monitoring of conditions

Sediment characterization

Three characteristic sediment fractions were found: 1) A fine sand fraction with a diameter of approx. 200µm; this fine sand has the same characteristic diameter as the sand found in the dune and dry beach area; 2) A clay fraction with characteristic diameter of 10µm, *i.e.* the same characteristic size as the clay from the older parts of the intertidal zone; 3) A (coarse) silt fraction with characteristic diameter of 60µm; this fraction only appears in a limited number of samples and its origin is unknown.

Due to the large variability of the sediment distribution of the individual samples even in locations that are relatively close, it was very difficult to get a synoptic view from the point measurements. Therefore and to obtain an area-covering picture, airborne hyperspectral remote sensing techniques were used. They allow a relatively good spatial and spectral resolution, though they can never compete with actual field measurements. Three images were available: one image from the Digital Airborne Imaging Spectrometer (DAIS) in 2001 and two images from the Compact Airborne Spectrographic Imager (CASI) in 2001 and 2003 [details are given in Toorman *et al.* (2004); Adam (2004); Adam *et al.* (2005)].

Soil erosion strength is an important factor for the stability of the surface to hydrodynamic forces. Vanhonacker (2004) carried out an in-situ erosion test. Values found for the erosion strength of the soft mud and estimates of the bottom shear stress from maximum flow velocities in certain zones on the tidal flats obtained from a hydrodynamic model (see below), are of the same magnitude pointing at a dynamic system and locally at a potential for surface erosion.

Topographic measurements

A digital elevation model (DEM) was derived from a LIDAR scan (18 December 2002). Results were used to construct lines of equal tidal means in Fig. 2. The resolution is about 1 point per $4m^2$ with a standard deviation of 7cm for the vertical positioning. Unfortunately no other LIDAR campaigns for this area have been done since; a detailed balance for the area could therefore not be made. At regular intervals along the transects, detailed ground level measurements were done in four consecutive summers (2001-04; two exemplary transects are given in Fig. 3). At six locations detailed measurements were done on a monthly basis, using a so-called ‘Sedimentation-Erosion Plot’ (SEP; Fig. 3).

The topographic measurements along the transects suggest a smoothing of the intertidal areas that were created by the restoration works (Fig. 3). At a number of locations erosion is visible, particularly along the northern edge of the former tidal dock, where the large stones (part of the former embankment) have resurfaced. This trend was foreseen in the feasibility study for the nature restoration plan (Hoffmann *et al.*, 1996) since old maps showed a recess at the same location. The concave shape of some of the transects also points at an erosion behaviour, but other transects have a convex shape indicating either stable or accumulating tidal flats (Fig. 3). The SEP-plots, that were installed at critical locations in the newly created intertidal areas show quite contrasting sedimentation-erosion patterns, ranging between an overall 25cm height increase (Fig. 3) and 60cm height decrease. However, most of the topography changes are rather small and yearly sedimentation and erosion budget changes appear to be slow.

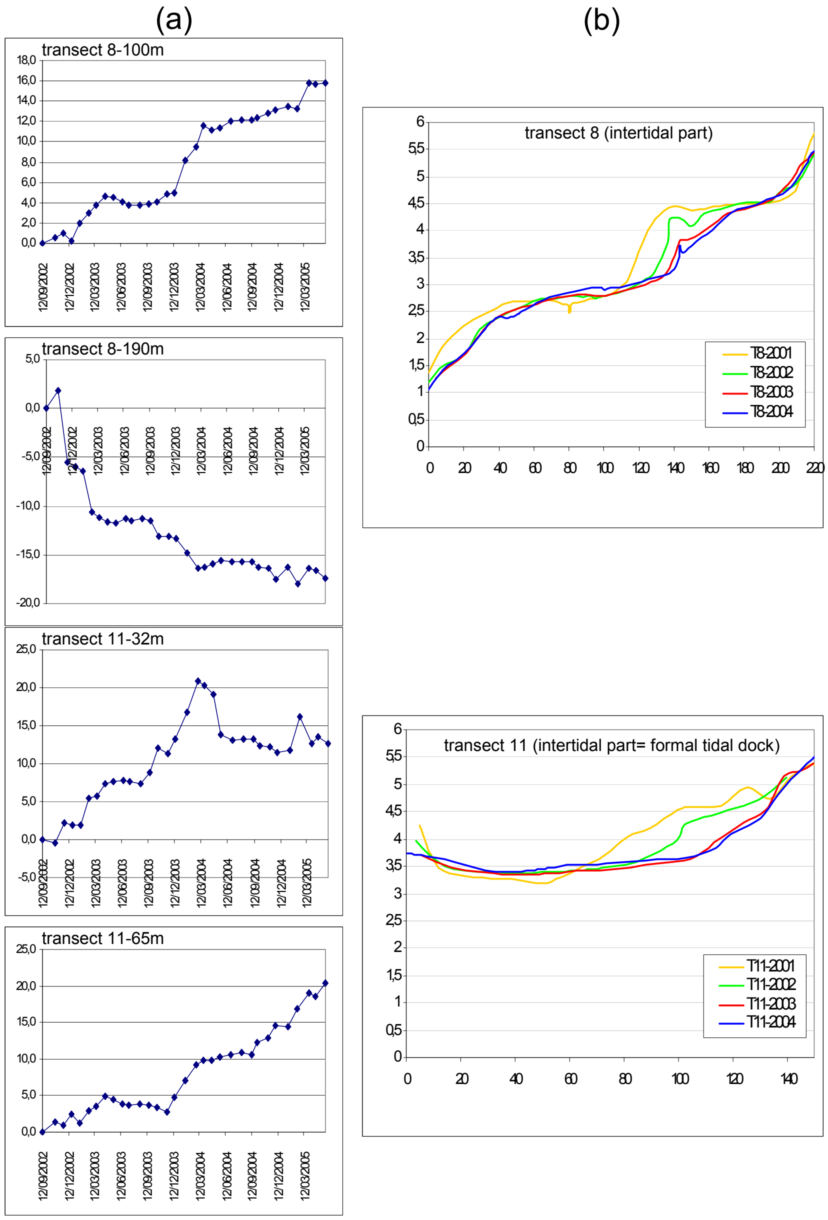

Fig. 3. (a) Monthly topographic measurements (September 2002 - June 2005) at four contrasting SEP-sites; y-axis indicates relative topography change in cm; (b) Topographic measurements in two transects in four consecutive years (summer 2001- summer 2004); y-axis in m TAW. The location of SEP's and transects are given in Fig. 2.

Hydrodynamic modelling

The hydrodynamic conditions are the determinant for the dynamic system of sedimentation and erosion in the area. In order to understand this system better, detailed numerical modelling can be useful. Caluwaert (2002) and Nolivos and Choudhury (2004) have made a 2D-vertically integrated numerical model of the study area using the TELEMAC modelling system. The calculated depth averaged flow velocities agree quite well with in-situ ADCP measurements. Work on morphodynamic modelling is ongoing, using the TELEMAC modules for bed load and suspended sediment transport.

Monitoring of key-stone biological variables

Macrobenthic fauna

(Macro)Benthic organisms are a vital component of any estuarine ecosystem. Not only do they represent an important part of biodiversity as such, they are an indispensable link in the food chain, e.g. as food for the typical estuarine benthivorous bird populations. Therefore, much monitoring attention was given to the benthic macrofauna in order to describe its biodiversity, its biomass and its colonisation of the newly created intertidal habitats (Wittoeck *et al.*, 2004). Sampling was done at low (+1m MLLWS), intermediate (+2.5m MLLWS) and high (+4.5m MLLWS) intertidal level, in several transects throughout the entire intertidal area, during three sampling events (Oct 2001-Sep2002-Jan2004). Sediment samples were taken for Coulter counter analysis of the sediment size distribution. The mudflats around an old creek (the Creek of Lombardsijde) served as a reference for the evaluation of benthic fauna development of the newly created intertidal area, since these mudflats were not directly influenced by restoration works.

The reference showed a significantly higher silt content than the newly created intertidal sections (the so-called disturbed sections); they all showed a more coarsely-grained substrate.

In all, 44 macrobenthic taxa were identified. Total number of individuals ranged from 0 to 113,100 individuals.m^{-2} with a mean density of 16,509 ± 2,334 individuals.m^{-2}.

In general, a significant negative Spearman rank correlation (r_s= 0.41; $p<0.0001$) was found between median grain size of the sediment samples and macrobenthic species richness: the coarser the sediment, the lower the species richness. A similar negative correlation was found between macrobenthic density and median grain size (r_s=-0.36; $p<0.0001$), indicating the primary importance of silt content of the sediment for macrobenthic fauna.

A clear differentiation appeared along the altitudinal intertidal gradient (low-intermediate-high). In general, lowest densities were found in the lower part (+1m MLLWS), highest densities in the intermediate part (+2.5m MLLWS) and intermediate densities in the upper part (+4.5m MLLWS) of the intertidal section of the ecotone.

The more sheltered intertidal area showed relatively low macrobenthos density and biomass. This can possibly be explained by the coarsely-grained substrate of this section at the beginning of the project. Only locally a thin layer of silt was deposited during the past three years, not allowing the establishment of a benthic macrofauna (yet). Above that, the area is situated at the higher altitude of the intertidal gradient (Fig. 2), which proved to be poorer in species and densities than the intermediate heights.

When comparing all intermediate heights, disturbed habitats generally showed higher densities than the undisturbed reference, while total benthic biomass was significantly higher in the former tidal dock. Diversity, expressed in number of species, on the other hand, was lowest in the former tidal dock.
The most prominent species were the crustacean species *Corophium volutator* (70% of the samples), the oligochaete species Oligochaeta spp. (most of which (if not all) belong to the species *Tubifex costatus*) (62%) and *Tubificoides benedeni* (36%), the polychaete species *Nereis diversicolor* (45%), *Eteone longa* (24%), *Heteromastus filiformis* (22%) and *Pygospio elegans* (21%) and the mollusc species *Macoma balthica* (29%).
In time, the total number of benthic macrofauna species steadily increased from 14 in 2001, over 18 in 2002 towards 25 in 2004. Some month after restoration works were finalized, the mudflats showed on average 4.5 species.dm^{-2}. This number increased steadily during the monitoring period until January 2004 (after approx. 3 years) to 5.5 spp.dm^{-2}. Macrobenthos density on the other hand did not show a steady trend through time, probably due to much stronger season dependent density trends. Highest densities were found in the summer samples of 2002. At intermediate altitudes within the intertidal gradient, species diversity was always higher (5-9 spp.dm^{-2}) than at high and low altitudes, respectively.

Avifauna

The Yser Estuary has always been an important resting and foraging area for wintering and migrating bird species. It has never been extremely important for breeding birds, unless the inner dunes, which are long known for their small, but regionally important breeding population of Northern Wheatear (*Oenanthe oenanthe*).
Water birds were regularly counted during high water, when all birds are concentrated on high tide roosts within the nature reserve. During the monitoring period (July 2001 – June 2004), 109 bird counts were realized. Counts were more frequent in winter than in summer, but all seasons were dealt with. Included in the counts were divers, grebes, herons and egrets, cormorants, swans, geese, ducks, waders and terns. Gulls were not systematically counted.
The total number of water birds reaches quantities of up to 5000 individuals in February (more detailed information in Devos and De Groote, 2004). Expressed in number of bird days, figures raise to more than 170,000 in January-February. On a yearly basis, Oystercatcher (*Haematopus ostralegus*; throughout the entire year) and Dunlin (*Calidris alpina*; concentrated in winter and early spring) are by far the most prominent water birds (together ca. 50% of total bird days), but strong seasonal differences appear; *e.g.* ducks, cormorants, gulls and terns are relatively more prominent in summer, while waders are by far the most frequent water birds in winter.
Since restoration activities started, the number of bird days of Redshank (*Tringa totanus*), Dunlin and Common Ringed Plover (*Charadrius hiaticula*) increased significantly (comparison of pre and post restoration period of two years each) with more than 50%, while the number of Oystercatcher, Black-bellied Plover (*Pluvialis squatarola*) and Ruddy Turnstone (*Arenaria interpres*) increased with up to 15% (increase not significant though).
As soon as new non-vegetated higher intertidal area and lower sandy substrate became available, pioneer breeding species as Kentish Plover (*Charadrius alexandrinus*) and

Little Ringed Plover (*C. dubius*) appeared in small numbers. In 2005, the first frequent breeding activities of Avocet (*Recurvirostra avosetta*) and Common Tern (*Sterna hirundo*) were recorded.

Flora and vegetation

Being the biological foundation of most terrestrial ecosystems, vegetation is often a basic monitoring item in nature restoration and management projects. Being a multivariate variable, vegetation as such is difficult to monitor though, let alone to evaluate, since no clear-cut criteria are available to judge the distance-to-target of vegetation. On the other hand, vegetation relevés give relevant, quantitative information on the flora at a higher resolution level than individual floristic data. To combine pros and cons of both, flora data on rare and dune specific or habitat indicator species were collected for the entire area, while vegetation data were collected systematically along transects perpendicular to the most important ecotones (Fig. 2). Vegetation changes were followed through yearly sampling of permanent plots. In 2001, 181 permanent plots were led out in 11 transects, in 2003 the number of plots was increased to over 500, the number of transects was raised to 13. Evaluation of the first successional trends was done after three years of monitoring (2001-2004; Hoffmann *et al.*, 2004). Eighteen different vegetation types were distinguished, using structural and quantitative floristic criteria. At least the intertidal types were clearly differentiated according to relative flooding frequency (Fig. 4).

Already in the first year after restoration, newly created intertidal areas were colonized by annual salt marsh species; habitat specific annuals appeared equally rapid in the appropriate sandy habitat at the floodmark (*Salsola kali* ssp. *kali, Cakile maritima, Beta vulgaris* ssp. *maritima, Atriplex littoralis*). Most abundantly establishing salt marsh annuals were *Salicornia europaea* and *Suaeda maritima* and to a lesser extent *Salicornia procumbens, Spergularia marina* and *S. media*. They gave the newly created, more or less sheltered, initially bare, silty intertidal habitats a truly vegetated appearance within two years after creation. The more exposed, and the sandier, new intertidal habitats on the other hand were colonized only slowly and sparsely, until recently giving them a rather bare non-vegetated sand flat appearance. Perennial salt marsh species did not yet or only very rarely (*Limonium vulgare*) colonize the newly created intertidal areas, not even the sheltered locations. This differentiation between annuals and perennials is well related to the seed bank data, showing the abundant presence of salt marsh annuals and the well nigh absence of perennial species (Bossuyt *et al.*, 2005).

Plant species that were formerly registered from the area, but that disappeared during the last decades (*Armeria maritima, Parapholis incurva, Juncus maritimus, Carex extensa, C. divisa, Halimione pedunculata, Oenanthe peucedanifolia, Trifolium squamosum*; Pire, 1862; Goetghebeur, 1976) did not re-establish yet. Pleasant exception is the recent reappearance of *Carex distans*.

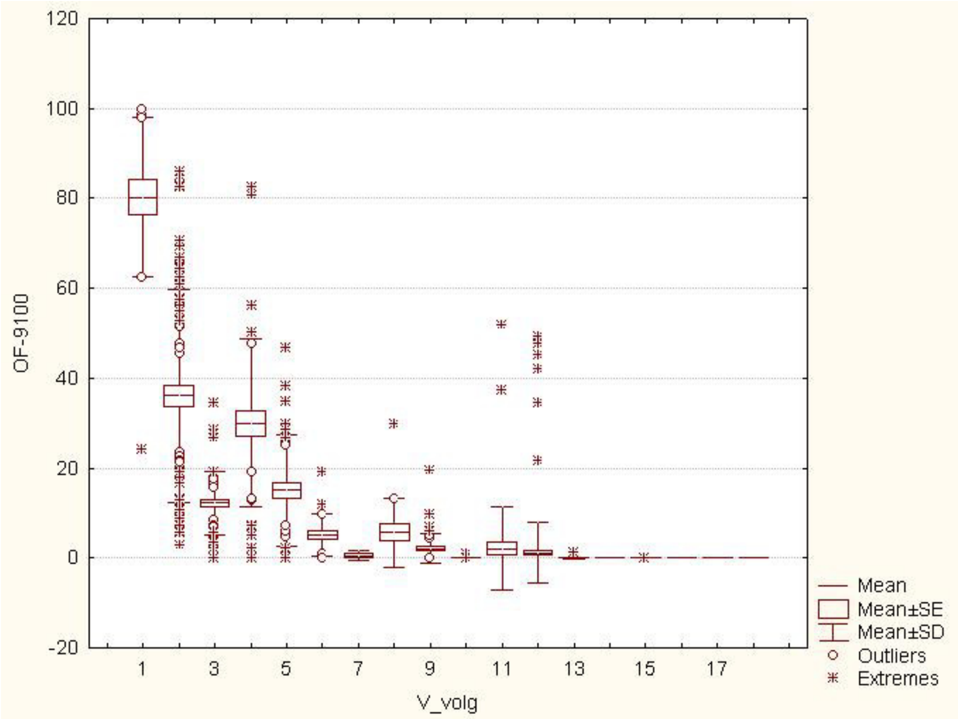

Fig. 4. Relative flooding frequency range of all 18 vegetation types, that were distinguished in 523 permanent plots in 13 transects along the salt marsh – dune ecotone in the Flemish nature Reserve 'the Ijzermonding': 1: Spartinetum townsendii; 2: Salicornietum brachystachyae; 3: Suaedetum maritimae; 4: Puccinellietum maritimae; 5: Atriplici-Elytrigietum pungentis; 6: Chenopodietum rubri; 7: Saginion maritimae; 8: Atriplicetum littoralis; 9: Honckenyo-Agropyretum juncei; 10: Ammophiletum arenarii; 11: Bromo-Corispermetum; 12: Echio-Verbascetum; 13: Phleo-Tortuletum ruraliformis; 14: Sileno-Tortuletum ruraliformis; 15: Festuca-Galietum veri; 16: Cladonio-Koelerietalia; 17: Hippophaeo-Sambucetum; 18: RG Urtica dioica [Galio-Urticetea]; OF91-00: calculated flooding frequency of the altitude at which the plots are situated; syntaxonomical nomenclature follows Schaminée et al. (1995). Classification is largely based on the outcome of an ASSOCIA-analysis (van Tongeren, unpubl. programme).

Terrestrial arthropods

Results of part of the monitoring efforts on terrestrial invertebrates (ground beetles and spiders) are reported elsewhere in this volume (Desender *et al.,* 2005; for more details, see Desender *et al.,* 2004). Spiders and ground beetles were sampled with classical pitfalls, located at several sites along nine transects within the study area (Fig. 2) and at ten sites that are already monitored long before this monitoring project started (Desender *et al.*, 2004). Per site three replicas were installed. Other invertebrates that were studied belong to the Diptera (flies) (details in Grootaert *et al.,* 2004). To investigate flies and flying activity of other arthropods white, water traps (Pollet and Grootaert, 1994) were used, during three consecutive years. In 2003, supplementary interception traps in the form of window traps were used to sample flies.

A quick colonisation of the newly created habitats by target Empididae (dance flies) was observed. These new habitats also attracted new Empididae species that were never found before in the area, while recent disturbance due to the restoration activities, (temporarily) caused target species of specific habitats to be found in other habitats as well. During the monitoring period three species of Asilidae (robber flies) were found of which one was new for the Flemish coast, while four species of Bibionidae (March flies), six species of Therevidae (stiletto flies), one species of Bombyliidae (bee flies) and five species of Stratiomyidae (soldier flies) were caught.
Special attention was given to the Dolichopodidae (long-legged flies) (details are given in Pollet, 2004). At least 47 species could be identified, including some very rare and red list species (40% of all identified species). Approx. 36% are typical representatives of river banks, while approx. 22% are more or less specific for coastal dunes. Over the three years of investigation, a gradual increase in species richness was observed at all sampling sites. Moreover, four critically endangered to fairly rare Dolichopodid species that are typical for coastal riparian or littoral habitats were recorded here for the first time. On the other hand, four species that were previously known from the intertidal environment were not recorded again/yet. It was concluded that the newly created habitats contain a relatively rich Dolichopodid fauna with several typically coastal species.

Evaluation

Monitoring is primarily focussed on the distance-to-target evaluation of initiatives, taken to reach certain nature restoration or nature development goals. The primary goal of this particular project was the creation or restoration of estuary-dune ecotones. Has this goal been achieved already after only three years?

Abiotic conditions

Indeed, the estuary-dune ecotone has been restored or created, showing continuous gradients of *e.g.* salt-fresh water, mud-sand, wet-dry, dynamic-stable. Nonetheless, most monitoring partners conclude that the degree of silt sedimentation in the lower part of the ecotone seems to be low to very low. It was shown that silt content is significantly lower at the newly created intertidal habitats than at the reference site (Creek of Lombardsijde). Topographical measures along transects have proven that no net sedimentation seems to occur, at some places (sometimes severe) erosion takes place, at others (sometimes strong) sedimentation is at work. This might very well mean that the system is evolving towards an internal equilibrium, but might also indicate that it receives no external sediments from the river. Although nothing definite can be said about the sediment-erosion balance yet, sediment input is surely vital for natural and spontaneous salt marsh development.
In connection with the dredging activities for the navigation channel, regular bathymetric surveys are done. Recent measurements of suspended material in the Yser point out that silt is mainly imported from the sea and hardly from the upstream part of the river. Most of this marine silt material is artificially exported again from the system through recurrent dredging activities. The recent deepening of the navigation channel (needed for dredging with a suction hopper dredger), will possibly have a further negative impact on

silt input to the intertidal mudflats and salt marshes. Marine silt material that is deposited at a lower level in the deepened navigation channel, will less probably be re-suspended and transported to the mudflats and salt marshes than in the case of a shallower channel.

The middle part of the estuary-dune ecotone (the upper zone of the intertidal area) is well developed; data on aeolic transport are lacking though, reason why the abiotic development of this part of the ecotone is difficult to evaluate. The same is true for the upper part of the ecotone. Newly created dunes have been stabilized with marram grass (*Ammophila arenaria*) and appear to develop positively. However, these inner blond dunes show far less aeolic dynamics than the fore dunes and seem therefore to stabilize very quickly.

Biological responders

Restoration of abiotic conditions can never be the sole goal of a nature restoration project; of course the expected biological responders should react in a positive way. Did they?

The botanists found a clear relation between spontaneous salt marsh development and silt accretion in the intertidal area, sites rich in silt and right above MHW are almost immediately colonized by salt marsh annuals, other, sandier places are far less easily colonized and often with rather eurytopic, salt tolerant plant species. It is expected that *Elymus athericus* will quickly start to dominate the salt marsh in these conditions, since this very competitive species is favoured by sandy, well-drained and oxygen-rich soil.

Desender *et al*. (2005) are also not convinced that the newly arrived typical salt marsh ground beetles and spiders will permanently establish, since they expect the dominance of sand above silt accretion to have a negative effect on the natural development of a typical salt marsh system and will endanger the maintenance of pioneer stages on the salt marsh.

Observations of the benthic macrofauna show a clear positive relation between silt content and benthic biomass and diversity. On the other hand, the benthic fauna seems to colonize the newly created intertidal habitats very quickly. Densities are already in the same order of magnitude as those found in comparable estuarine habitats from climatologically similar locations, such as Balgzand (Wadden sea; Beukema, 1979), Königshafen (Reise, 1985) and the Westerschelde (Ysebaert, 1993, 2003). Benthivorous bird species, e.g. Redshank, Dunlin, Oystercatcher and all three Plover species, forage very frequently in the newly created intertidal habitats (De Groote, 2003) and have increased in number since the intertidal area was enlarged. The enlargement alone explains at least partly the recent and frequent breeding activities of several water bird species.

It can be concluded that the creation of intertidal area is very positively evaluated, but that the sediment-erosion balance remains a critical bottle-neck. All monitoring partners conclude that further systematic monitoring is vital to further evaluate abiotic and biological changes in the still very young and quickly evolving ecosystem.

Instead of typical fore dune marram dune development, the created inner dunes in the upper part of the ecotone (above MHWS), rather show a development of more or less ruderal, pioneer vegetation among the planted marram grass. No colonization of typical fore dune species occurred yet, but both ruderalisation and the lack of colonization by typical marram dune species are expected to be temporary phenomena.

Monitoring problems and further monitoring

Monitoring should be a recurrent element of every nature restoration and management process (Fig. 1). Since the evaluation of distance-to-target is an intrinsic part of the monitoring process, one needs initial goals with well-defined standards. Although a system of nature typology has been developed for Flanders (http://www.inbo.be), enabling managers to define restoration and management goals, a quantifiable standard per nature type has not yet been developed. Developing such a generally applicable standard remains a hard job to do, because of the multivariate character of every nature type and because of the local specificity of every single nature reserve and nature restoration project. Above that, not all people involved in nature conservation, development and management are convinced of neither the possibility nor the necessity to force nature into the deterministic straitjacket of pre-defined nature target types. Nonetheless, we consider it important to develop such a system in order to be able to quantify the distance-to-target and hence to be able to evaluate result commitments.

To judge the changes in environment and biodiversity after nature restoration initiatives, monitoring should be continued much longer than an initial period of three years. Changes on the short term can be due to seasonal fluctuations or due to population density fluctuations of the target species in general. Above that, biotic response variables, such as vegetation, generally react slowly on changed conditions.

In the nature restoration project at the Yser Estuary, monitoring was very intensive during the first three years, and therefore very time-consuming and costly. The further follow-up can be simplified and made less intensive in time (*e.g.* surveys every one to five years, depending on the variable to be surveyed) and space (not all 13 transects and with vegetation plots every 5m, but *e.g.* a number of plots per vegetation type or per ecologically defined part of the ecotone). Monitoring can also and perhaps preferably be focussed on a selection of positive and negative process indicators (see *e.g.* Desender *et al.*, 2005; Van Dyck *et al.,* 2001; Maes and Van Dyck, 2005; Van Reeth and Vanongeval, 2005), which are sensitive to changes in the environment.

New measures, such as the recently introduced grazing by sheep on the tidal marsh, should again be followed intensively at the beginning. The sedimentation-erosion budget should be estimated on a regular basis, certainly if positive measures (*i.e.* changes in external water management measures, ensuring better chances for silt input) are possible. Area-covering vegetation mapping would best be realized every five years.

Monitoring continues for terrestrial arthropods (spiders and ground beetles), vegetation, flora and avifauna. For the further follow-up of the sedimentation balance, it has been chosen to further develop the area-covering interpretation of hyper spectral images (part of a recently started FSR-project). Next to that SE-plots are further followed and transects are measured on a yearly basis. Sheep grazing impact on vegetation is monitored rather intensively through an ex-/enclosure technique and through research on habitat and diet selection of the sheep, using the instantaneous sampling method (Lamoot *et al.*, 2004). All these monitoring initiatives are taken by the research groups themselves, of course in mutual consultation of the manager of the Flemish nature reserve, being the Nature Department of AMINAL (Ministry of the Flemish Community).

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