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Development of a decision support system for LIFE-Nature and similar projects: from trial-and-error to knowledge based nature management

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Abstract

The very high environmental pressure on ecosystems increases the need for active nature management. Compared to classic nature conservation this requires a considerable knowledge of ecosystem functioning, in particular about the biotope conditions required by plant and animal species and the biogeochemical processes and hydrology structuring these conditions. The amount of available knowledge on these subjects has increased rapidly and restoration projects are becoming more and more successful. However, recent evaluations show that in a majority of the projects the results are still far from optimal. One of the most frequently occurring reasons for the variable results is a poor availability of essential information to restoration managers. In particular information for analysing the basic problems, setting the right objectives, and planning effective restoration measures is lacking. A decision support system that offers easy access to up-to-date knowledge could help to increase success rates. The main aim of a running LIFE-Nature Co-op project is to develop and test such a tool for coastal dunes and raised bogs and to bring together relevant experience and knowledge on the conservation and restoration of these vulnerable ecosystems. The decision support system will assist site managers to take the proper steps in their nature restoration project: 1) description of the problem and its consequences for the functioning of the ecosystem and the presence of species, 2) analysis of the processes that have caused the problem, 3) selection of the best possible restoration objective, 4) description of restoration measures necessary to achieve the objectives, 5) development of a plan for monitoring the effects of the measures and 6) execution of the measures and monitoring. This decision support system will be accessible via an interactive interface that selects the information relevant to the user's situation. All essential information will be presented in short texts, supported by pictures of field situations. Furthermore, links to relevant literature and to field examples will be present. The latter refers to a list of recently carried out and ongoing projects, including addresses of the responsible authorities. The tool will be freely accessible on a website and can be easily updated with new knowledge and experience. Thus, an easy exchange of essential knowledge and experience is stimulated.

Keywords: Objective; Conservation; Restoration; Knowledge; Decision support system.

Introduction

Throughout Europe, nature managers try to restore ecosystems that have suffered from various threats such as drainage, habitat fragmentation, acidification and eutrophication. Compared to 'classic' nature *conservation* - which is ideally restricted to the exclusion of anthropogenic influences from nature reserves – the *restoration* of ecosystems requires a more active attitude. If we want to be able to restore ecosystem functioning, a profound insight in the key-processes is essential. We need to know which processes have led to degradation of an ecosystem, on what scale they operate, how they interact with the ecosystem and how they affect the occurrence of species. With increasing insight in ecosystem functioning as well as experience in carrying out restoration projects the success rate of nature restoration projects grows. There are however several problems and pitfalls in nature management that seriously hamper the process of increasing success rates. One of the largest problems is the poor availability of essential knowledge on ecosystem functioning for managers who plan restoration measures. Recent surveys show that only in 2.4% (Sutherland *et al.,* 2004) to 8% (Pullin et al. 2004) of all analysed project plans scientific knowledge was used in planning restoration measures. Furthermore, many management interventions remained unevaluated and much information is not readily accessible in suitable form (Pullin *et al.,* 2004). A limited exchange of practical experience between different projects is also mentioned by Houston (1997). All authors mention an urgent need for a conceptual framework to make evidence-based knowledge and practical experience accessible in nature restoration.

In this paper we present the basic design of a decision support system that can help nature managers in planning effective restoration measures. This tool will not supply complete designs for specific nature areas. The system points out how general problems and pitfalls in restoration management can be foreseen and avoided and supplies essential ecosystem knowledge to nature managers. Though the decision support system can eventually be used in all types of ecosystems, efforts are now restricted to restoration management in coastal dunes and raised bogs. In this paper the most important problems and pitfalls in nature restoration are mentioned and illustrated and the basic design of the decision support system will be explained.

Problems and pitfalls in nature restoration

We consider restoration projects successful if natural processes and abiotic conditions are restored (as best as possible under present ecological stress factors) and if populations of characteristic flora and fauna species are restored. By this definition only few restoration projects can be considered completely successful. In many projects, only a part of the processes and abiotic conditions are restored and only a small number of characteristic species are facilitated by the measures taken. For example, in Kooijman et al. (in press) 21 restoration projects in dry coastal dunes in The Netherlands are evaluated, including mowing, sod-cutting, grazing and reactivation of blow-outs. Although most measures show positive effects after 5 to 10 year, none of the measures has led to a more or less complete restoration of floral biodiversity. Effects on fauna are not studied in these projects, but in general they seem to be less positive than effects on vegetation (Van Turnhout et al. 2003). In another evaluation of nature restoration projects in Dutch coastal dunes (Van den Boom *et al.,* 2004), only 5 out of 33 projects

were considered successful, 16 projects showed partial positive effects and 11 projects showed hardly any positive effects. Two projects were carried out too recently to draw conclusions on the effects. In a number of restoration projects populations of characteristic plant or animal species became locally extinct due to negative side effects of restoration measures. If these species cannot recolonise from nearby populations these side effects must be considered as a partial failure of the project.
To increase the success rate of restoration measures and to avoid negative side effects, a number of problems and pitfalls must be discerned. Although the described problems and pitfalls in nature restoration seem very obvious, practice shows that in a majority of restoration projects one or more of the aspects mentioned is overlooked or undervalued!

Problems or restoration objectives are not well defined

Restoration can be focused on certain species, taxonomic groups or on a certain aspect of the ecosystem only. In this way, one can easily overlook concomitant problems or conclude that a certain measure is successful, whereas characteristic species that were out-of-focus did not recover or even disappeared from project areas. For example, during the first years of the very successful Dutch 'survival plan for woodland and nature' (OBN), measures against acidification were included in only 33% of the projects, whereas more than three-quarter of the ecosystems involved suffered severely from acidification (Van der Burg and Brouwer, 1993). In this same program, the restoration goals were mainly defined by abiotic and floral parameters. A recent evaluation showed that a part of the characteristic animal species was not or negatively influenced by restoration measures (Van Duinen *et al.,* 2004). In an evaluation of restoration measures in the coastal dunes of the Netherlands (Van den Boom *et al.,* 2004) the objectives were clearly defined for 18 out of 33 restoration projects. In 12 projects the objectives were defined too narrow (*e.g.* only based on hydrology) or too broad (e.g. 'creating open dune landscape' or 'increase of plant species diversity'). For 3 projects no objectives were defined. Only in 2 out of 33 projects fauna species were included in the objectives.
In some restoration projects the measure itself (*e.g.* 'raising the water table' or 'grazing') is presented as an objective. This was (partially) the case in 5 out of the 33 dune restoration projects evaluated by Van den Boom et al. (2004). In such cases there is a risk that restoration is declared successful when the measure is carried out in the right way (e.g. water tables do raise or cattle is active in the whole restoration area), irrespective of the effects on the ecosystem.
Sometimes ecosystems which are already degraded are used as a reference in planning restoration measures. This can lead to the wrong analyses of the problem or a wrong definition of objectives and subsequent evaluation of the measure. For example, the effects of mowing on plant species richness in dune grasslands which are encroached with shrubs or tall grasses were evaluated as relatively successful, since species richness was restored to 65-80% of the best sites before measures were taken. However, plant species diversity in these 'best sites' was already severely decreased compared to intact situations (Kooijman *et al.,* in press).

Insufficient insight in ecosystem functioning

The processes that have caused the problem are not or insufficiently known. The consequences of the applied measures, including negative side effects, are therefore incalculable. If knowledge of such key-processes is insufficient, then essentially a trial-and-error approach is applied. A recent evaluation of 12 Dutch restoration projects in coastal dunes showed that in a majority of the projects, some goals could not be met due to "unforeseen" reactions of the ecosystem (Graveland and Esselink, 2004). Also Van den Boom et al. (2004) mention two dune restoration projects in which the results differ strongly from the restoration objectives. For one of these projects and for another project in which the results were disappointing, insufficient knowledge on local conditions were mentioned as an important reason.

No or insufficient monitoring before and/or after the measure

The situation before restoration is not properly described. This may be a consequence of a too narrow definition of the problem and restoration objectives for the project area, since the parameters that are monitored do not indicate the relevant ecosystem changes. Also the monitoring period can be too short. In acidified and/or eutrophied wet dune slacks *e.g.*, seeds of characteristic plant species germinate after removal of accumulated organic matter, but these species can subsequently disappear after a few years due to re-acidification or re-eutrophication (Brouwer *et al.,* 1996; Grootjans *et al.,* 2002).

Scaling and timing of measures is not optimal

Restoration measures affect the present biodiversity, including characteristic or target species. If the scale of these measures is too large or if they are carried out in the wrong season or in a very limited period of time, the number of negatively affected species can rise alarmingly. On the other hand, an evaluation of Dutch coastal dune restoration projects has shown that measures that are designed to revitalise large-scale processes are unsuccessful if applied on a small scale (Graveland and Esselink, 2004).

The PROMME-concept for restoration management

In order to accelerate the process of optimizing the results of restoration projects, a LIFE-Nature Co-op project was started that brings together and disseminates the experience and knowledge of site managers and ecologists all over Europe. A decision support system for setting up restoration projects will be developed and will be freely accessible via an internet site. The system will include all ecological knowledge essential for successful restoration. In this project, we restrict our efforts to two types of ecosystems: coastal dunes and raised bogs. This LIFE project, entitled “Dissemination of ecological knowledge and practical experiences for sound planning and management in raised bogs and sea dunes”, is carried out by the Radboud University Nijmegen in close collaboration with site managers and scientists from other European universities and institutes. At this moment approximately 60 persons from 30 institutes in 12 European countries participate in this Co-op project. In the following, we describe our approach and the first results of this project.

In nature restoration projects, many aspects have to be considered. Sufficient funding has to be raised, stakeholders need to be informed, public acceptance must be sufficient (*e.g.*, Edmonson and Velmans, 2001; Zwart, 2001), and the whole process needs to be carried out according to all kind of legal and administrative rules. In our project we acknowledge the importance of these aspects, but we focus on the ecological aspects and actual restoration process. Based on the experiences with many restoration projects, we made a checklist for a successful application of restoration measures. It shows which steps are essential and in which order they should ideally be carried out. At the first workshop of the LIFE Co-op project in October 2004, the PRIME-concept (Problem-Reason-Instrument-Monitoring-Execution) was launched and after discussing this concept with the participants, some adjustments were made. It was felt that the phase of setting the objective of restoration projects needed to be addressed in a separate step (in between the Reason-phase and the Instrument-phase of the PRIME-concept), thus resulting in the PROMME-concept (Table I). The decision support system must help with formulating realistic and clear objectives on various time and spatial scales. The PROMME-concept is designed to check for pitfalls in the restoration process and the decision support system will give access to information that shows how to avoid them.
The decision support system will provide help and detailed relevant information to go through any of the six PROMME-steps. The system can not provide a complete design for each specific situation itself, but will provide the user with the information necessary to design and carry out a restoration project on a specific site. The user will be encouraged to make the definition of the problem as complete as possible. The system will list possible causes for the problems in the project area and will support the user in selecting the most important ones in his or her particular case. Sometimes, information essential to define the problem or causal factors is lacking. The decision support system will help to identify this lack of knowledge and provide instructions for additional measurements or recommend the help of a specialist.
Based on the problems and their causes, as well as the opportunities and limiting factors in and around the project area, clear and realistic restoration objectives have to be defined. For every general problem and objective, sets of restoration measures will be provided. Adding information about specific problems or site conditions that the user has given will refine these sets. Recommendations for monitoring programs and parameters will be given and finally practical information necessary for the execution will be presented, including notes on the intensity and spatial scale of measures and feedback between monitoring results and the execution of measures. An easy access to the essential literature will be provided at different steps in the decision support system.

Problems and pitfalls in coastal dune restoration

The ecological functioning of coastal dunes depends primarily on the influence of flooding by the sea and on the shifting of nutrient poor, fresh wind-blown sand. Secondarily, the floral and faunal composition is a result of groundwater level, amount of decalcification and succession (Westhoff, 1971; Grootjans *et al.,* 1997; Kooijman *et al.,* in press). These processes result in a small-scale alternation of vegetation structures. The most important factors influencing coastal dune ecosystems in Europe are increased atmospheric nitrogen deposition, active stabilisation of shifting sand by planting marram

grass and pine trees and drainage of groundwater. These factors, in combination with a decrease of rabbit activity due to the diseases myxomatosis and RHD, stimulate the growth of grasses, shrubs and trees and thereby counteract the influence of natural dynamics. This leads to the disappearance of small scale vegetation patterns and its dependant fauna (Nijssen *et al.,* 2001a, Van Turnhout *et al.,* 2003).
Restoration of coastal dunes should primarily focus on the possibilities for the restoration of the natural dynamics (Ketner-Oostra 2001; Kooijman *et al.,* 2004). However, in many dunes one or more of the following ecological preconditions for this functioning are absent: a sufficiently large dune area, atmospheric nitrogen deposition below the critical load, access of the sea to a considerable part of the dune area, and a minimal amount of bare sand. These limitations have consequences for choosing realistic objectives by site managers and thus, for the restoration measures to be executed in the project area, as is illustrated in the example below.

Table I. The PROMME-concept, a checklist that contains six essential steps for nature restoration projects in order to avoid pitfalls

Step	Description	Pitfalls
Problem	Description of the problem in terms of changes in flora, fauna and abiotic conditions on certain spots and the consequences of these changes for the ecosystem as a whole.	• Important aspects (including species) easily overlooked. • Reference situation insufficiently known.
Reason	Analysis of the biological, hydrological, chemical, and physical processes which led to the observed changes.	• Key processes easily overlooked. • Other processes easily overvalued. • Specific site conditions not recognised.
Objective	Formulation of a restoration goal, based on the current possibilities to invert the processes that led to ecosystem degradation.	• Current limitations not considered. • Objective not well defined, excluding important parts of the system or species groups.
Measures	Selection of the optimal combination of restoration measures for restoring the ecosystem to the defined goal.	• Combination, scale, intensity and/or timing of the measures lead to extinction of the species present. • Negative side-effects of measures overlooked.
Monitoring	Selection of (a)biotic indicators for ecosystem recovery and start of monitoring.	• Parameters not indicative. • Monitoring only starts after execution of measures • Monitoring period too short.
Execution	Actual application of the restoration measures and simultaneous monitoring and feedback.	• Inexperienced executors. • Be prepared for unexpected situations.

Grazing as a restoration measure in grass-encroached grey dunes

Nitrogen deposition, active stabilisation of shifting sand and a decline of rabbits as natural grazers have led to grass-encroachment in many coastal dunes. Therefore, grazing with sheep, cows or horses has become a widely applied management tool. In many grazing projects, a decrease of tall grasses was observed, sometimes in combination with a return of characteristic plant species (*e.g.* Kooijman *et al.,* 2005) or a reduced decrease of these species (Packham and Willis, 2001). In these and in many other studies, grazing is therefore considered a successful restoration measure. However, a close inspection of the data shows that plant species returned in much lower densities than were present in the (sometimes already deteriorated) reference situation. Moreover, the reduction of tall grasses was mainly a decrease in height of the grasses and did not lead to a change in cover. Essential problems, such as acidification, accumulation of nutrients and organic matter and the absence of bare, sandy patches were not solved. Therefore, the typical flora and fauna did not return, as was shown for characteristic carabid species of dry open dunes (Nijssen *et al.,* 2001b). In one case (Burton, 2001), rejuvenation of small scale aeolian activity did occur after trampling by cattle and facilitation of fauna species like solitary bees and wasps and Natterjack Toad (*Bufo calamita*) was reported. However, in this project problems with tall grasses and subsequent accumulation of litter and humus seemed less serious, probably due to relatively low nitrogen deposition rates.

The decision support system aims to encourage restoration managers to optimize their results and gives access to the information that is needed to do so. When dealing with grass-encroachment of grey dunes the PROMME-based decision support system at least the following aspects will be considered:

- The basic problem is disappearance of characteristic flora and fauna species of grey dunes. To recognize the impact of the problem it is of major importance to have a reference situation (in space or time) in an intact grey dune system. Also the scale on which the problem occurs in relation to the total size of the dune area is important.
- When describing the reason, problem managers will be stimulated to consider more aspects than the obvious ‘encroachment by tall grasses'. What is in a specific situation the key factor for encroachment? Has encroachment started after ceasing human activities? Can increased nitrogen deposition levels be (part of) the problem? Did rabbit populations decrease? Also other processes can be involved such as accumulation of litter and/or humus or decrease of aeolian activity.
- The general objective is to facilitate populations of characteristic flora and fauna species by restoring the abiotic conditions and processes of the ecosystem. This means that not only tall grasses should be removed, but maybe also bare sandy patches or aeolian activity should be restored or the pH of the top soil should be increased. To formulate the right objectives in sufficient detail a list of characteristic ('target') species, knowledge on the resident flora and fauna and in particular the distribution of rare and characteristic species, and knowledge of the (a)biotic conditions required by the respective species is indispensable. To set realistic objectives limiting factors have to be considered, such as size of the area, recreation pressure or ongoing stress factors like high nitrogen deposition rates.
- Choosing the most effective measure (or set of measures) depends on the set of objectives, the causes of the problem, as well as the resident flora and fauna species that should be taken into account. When the objective is to remove tall grasses and

create small scale aeolian dynamics, grazing can be sufficient in sites where no humified soil has developed, but is probably insufficient in places where such a soil layer is present. In the last case, other measures like small scale sod-cutting can be applied. Of course, the type of grazer and the grazing intensity should be tuned to the objectives. The scale of the measures depends on the scale of the problem as well as on the presence of populations of characteristic species or vulnerable vegetation types in grey dunes *e.g.*, lichen-rich grasslands. To spare these species and vegetation types measures can be carried out on a smaller scale, phased in space and time, or certain parts of the area can be exclosed.

- Monitoring is necessary to evaluate the efficiency of the measures taken and provides information needed to chose the proper timing of subsequent steps in the restoration management, if measures are phased in time and space. Moreover, it creates the possibility to stop or fine-tune measures when negative effects occur. It is very important to choose parameters which indicate if the measure leads to desired as well as undesired situations. Monitoring should start well before the taking of measures, since the effect can only be determined when the starting situation is sufficiently known. Continuation of monitoring should be planned and secured beforehand for a period long enough to determine the effects of the measure.
- Execution of measures can take place after all aspects mentioned above are taken care of. Supervision by nature managers while carrying out the measures is recommended, especially when the measure is put out to a contractor with no ecological background.

An internet site for supporting restoration management

Site managers, being partners in the LIFE Co-op project will test the concept decision support system. An internet site containing the PROMME-concept and the decision support system for restoration of coastal dunes and raised bogs is planned to be operational in 2006. This tool will be free to use and will give access to up-to-date essential ecological knowledge on these two types of ecosystems, field examples and addresses of experienced site managers. When the decision support system proves to be a useful tool for site managers in LIFE-Nature and similar nature restoration projects, the system can be extended to other types of ecosystems.

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