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Inventory methods in relation to landscape history and structure

During the last few decades several nationwide, thematic nature inventories have been carried out in Sweden. The main purpose of these inventories was to map and assess conservation values in different habitat types in a uniform way. A lot of resources have been invested in the inventories and during the work many important experiences have been learnt. In this paper we would like to give a brief description of how the inventories have been conducted and also present some of the experiences that have been learnt.

The major inventory projects that have been conducted are:
The virgin forest inventory 1978-1983.

This was the first nationwide thematic nature inventory and the objective was to identify so called virgin forests (primeval forests with no traces of human impact). The inventory method varied between regions. In some cases aerial photographs were used to identify interesting sites, in other cases studies of maps or inquiries to local conservationists or foresters achieved the same purpose. Since this was a "first-step" survey, and the sites were sometimes very large, the fieldwork procedure was not particularly detailed. Negative human impact such as the occurrence of stumps were often used as a disqualifying criteria and only in very few cases were the assessment of conservation values based on the occurrence of particular species. This inventory has been the main base upon which the conservation of forests was built in the 1980's and the early 1990's.

THE VIRGIN FOREST INVENTORY
• Number of conservation value classes: 4
• Scale of maps used for reporting: 1:50 000
• Result: In total 418 sites with an area of 770 000 hectares (456 000 hectares forest area) were recorded in conservation value classes 1 and 2. More than 80% of this area consisted of so-called sub-alpine coniferous forests situated in the northern part of Sweden (Bråkenhielm 1982, Löfgren 1984, Löfgren 1986).

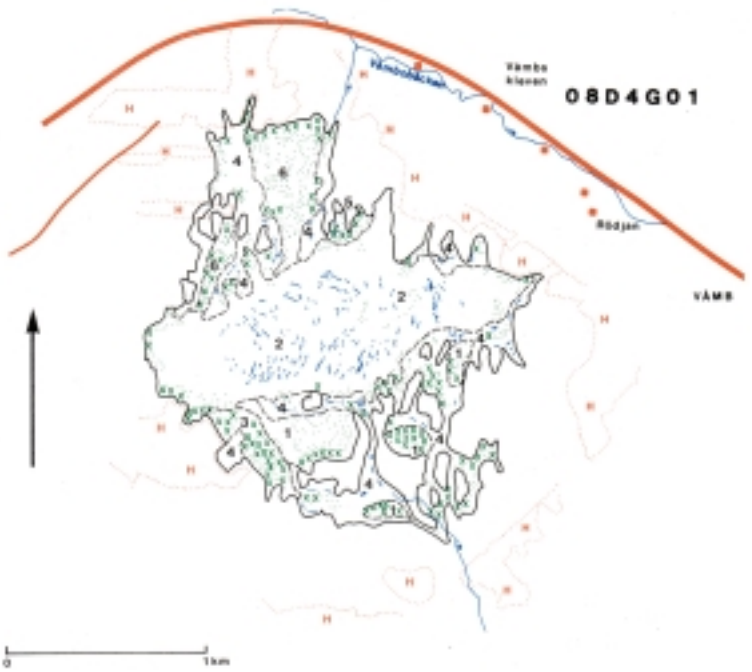

Figure 1. A MAP OF A WETLAND SITE *(Degramossen) from a wetland inventory report. The boundary of the wetland is copied directly from an aerial photograph. The numbers represent sub-units of a site consisting of different habitat types. The long blue lines are brooks and the short ones show the hollows in the wetland. The green crosses represent forest, mainly pine/spruce-forest, and the green dots are open grown trees. Red lines show the roads and the red "H"'s are clear cuts. The code in the upper corner of the map consists of a map code and a site number.*

THE WETLAND INVENTORY

- *Number of conservation value classes: 5*
- *Scale of maps used for reporting: between 1:20 000 and 1:60 000 depending on the scale of the aerial photographs (Göransson et al. 1983)*
- *Result: In total 26 000 sites have so far been recorded and of these, surveyors have visited ca. 4000 (http://www.environ.se/).*
- *Other information: Most of Sweden has been covered by the inventory except the northernmost part of the country where the work is still going on.*

The wetland inventory 1979 ➜

The main objective of this inventory was to map all wetland-sites larger than a certain minimum area to form a knowledge basis for future conservation work. Aerial photographs were used and 10-15% of the identified sites, estimated to be of the greatest importance were visited and assessed in the field. All other sites were described by using features that can be identified from the aerial photographs. The method was uniform for the whole country. All data collected during the inventory was stored in a database.

For the visited sites, data was collected at several different levels, for example vegetation-type including elements and structures (site-level) and species of vascular plants, mosses and lichens (vegetation-type level).

The work was carried out by biologists given special training. Due to lack of resources, field data is lacking from many potentially valuable wetland sites.

The inventory of meadows and pastures 1986-1991.

The objectives of this inventory were to map, describe and assess the conservation values of all sites containing grazed or mowed semi-natural grassland. Identification of sites was done by interpreting infra-red, aerial photographs and all identified sites were visited by a surveyor.

The minimum size of documented pastures was 1-2 ha but for meadows managed in a traditional way, no minimum size was applied.

The personnel who worked on the inventory (ca. 120 persons, mainly biologists) were given specific training.

The elements and structures found and recorded during the fieldwork were mainly those that were of cultural interest (stone walls, wooden fences, pollards, ancient monuments).

Vascular plants associated with unfertilized and well-managed grasslands were used as indicator-species. Data collected was stored in a national database but the database was not created until several years after the fieldwork was finished.

Figure 2.
An inventory of semi-natural meadows and pastures was conducted in Sweden between 1986 and 1991. The nature reserve Drottningkullen, in the Municipality of Skara, represents a good example of sites searched for during the inventory. Photograph by Artur Larsson.

THE INVENTORY OF MEADOWS AND PASTURES

• Number of conservation value classes: 4
• Scale of maps used for reporting: 1:10 000
• Result: 25 000 sites covering ca. 232 500 hectares, were classified and reported on. A large part of the sites identified from aerial photographs turned out to be fertilised by nitrogen and planted with spruce or birch, or had been without proper management for a long time. These types of sites were not recorded as they were not considered to be semi-natural grassland (Swedish Environmental Agency 1987, Lindahl 1997, 2001).

The woodland key-habitat inventory 1992 ➜

This inventory was aimed at delimiting and describing forest areas of particularly high conservation value (according to the definition, forest-stands that may contain red-listed species). The identification of sites was made by using forestry-plans, different types of maps, infrared aerial photographs, earlier inventories etc. Most of the identified sites were visited by a surveyor but due to lack of resources a number of potentially interesting sites were left unvisited. Important features of the inventory method were the use of parameters such as key-elements and indicator-species. All data collected was stored in a database and the data entry took place in close connection with the fieldwork. The National Forestry Board conducted the inventory in areas where the properties were smaller than 5 000 hectares (ca. 50% of the Swedish woodland area). The surveyors (ca. 150 persons - mainly foresters) had been given a thorough training. Owners of larger properties have either conducted the inventory themselves or hired consultants, for example personnel from the National Forestry Board.

Inventories of deciduous woodland

In some counties county-wide inventories of deciduous woodlands have also been conducted (1983). The objectives have been to map, describe and assess the conservation value of all sites containing deciduous forests (in some cases only forests dominated by oak, beech, ash, elm or lime). The identification of sites were made by using infra-red, aerial photographs and all identified sites were visited by a surveyor.

Practically all counties that have conducted this type of inventory are situated in the boreonemoral zone where 10 to 15% of the woodland area constitutes of deciduous forests.

The starting procedure

The starting procedure of these inventories has often been a heterogeneous, unpredictable and time-consuming process where indications of a strong threat against, or considerable decline in

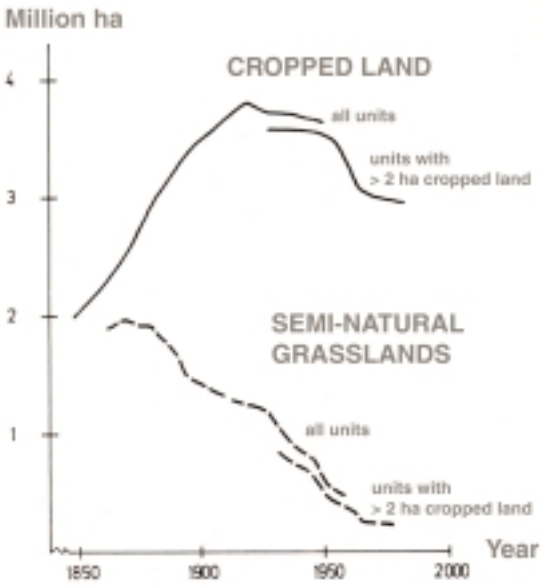

Figure 3.
A severe decline of semi-natural grasslands in Sweden occurred during the last century. This is an important reason why the Swedish inventory of meadows and pastures was started. From Larsson 1986.

THE WOODLAND KEY-HABITAT INVENTORY

• Number of conservation value classes: 2 - woodland key habitats (forests that may contain red-listed species) and areas of some conservation value (areas that, in the near future may contain red-listed species)
• Scale of maps used for reporting: 1:10 000
• Result: In forests belonging to small sized forestry organisations where properties are smaller than 5000 hectares, 40 000 woodland key habitats and 31 000 areas of some conservation value have been recorded (118 700 hectares and 101 000 hectares respectively) (Norén 1999, Nitare & Norén 1992) (http://www.svo.se/).

area of, a habitat type have made scientists, conservationists, authorities or media aware of the situation. Since performing a nationwide inventory is a very large investment to society, it is important to scientifically support the suspicion of a threat or decline before the project starts. This can be done, as in the wetland-inventory case, with a threat-analysis where it could be shown that a large proportion of all wetlands would be destroyed if the current rules for ditching were continued (Swedish Environmental Protection Agency 1980). Another example is the inventory of meadows and pastures, where it could be shown that there had been a severe decline of semi-natural grasslands during the last century (Larsson 1986).

COURSE OF ACTION

Many of the Swedish thematic inventories have been performed in a similar way. We will here briefly present the course of action.

Introduction phase. In the first phase of an inventory it is of utmost importance to clearly define the site-types that should be searched for. A clear definition will give a more indisputable result and will also prevent the surveyors from doing a lot of unnecessary work. The next step will be to develop an inventory method. This work depends on the resources available in terms of maps, forestry-plans, remote sensing techniques and existing knowledge about biotic and abiotic conditions. If definitions are lacking for habitat-types, vegetation-types, key-elements or indicator species such definitions must be produced. Also criteria for assessments of nature conservation values must be developed. Existing infrastructure on a local level can in some cases influence the method of development. If, for example, certain types of sites are very difficult to reach, this has to be taken into consideration. An important part of the method development is also to produce field forms and a proper database structure. When the method has been tested under realistic conditions and evaluated it should be presented together with a manual.

The introduction phase also includes the training of personnel. This training must ensure the personnel reach an adequate level of knowledge in terms of habitat identification, vegetation-type identification and identification of indicator species. Personal devotion to and enthusiasm for the inventory work have proven to be important for the quality of the result. To achieve a somewhat uniform assessment of conservation values of different sites the training must also include calibration between the surveyors.

Preparatory work . The most important part of the preparatory work is to identify, locate and, on maps, delimit sites of interest. In most cases infrared aerial photographs are by far the most powerful tool to use. In some cases interpretation of aerial photographs has to be supplemented with information from other sources such as forestry-plans, geological maps, literature or interviews with people who have good knowledge of local conditions. In some cases it can be a good idea to standardize this type of data collection by using a simple form.

In those cases where a surveyor will only visit some of the identified sites, the choice of sites is based on data collected during the preparatory work.

Field-work. During the field-work the first task for the surveyor is to decide whether the identified sites match the definition of site-types that should be searched for and if the delimitation of the site made during the preparatory work is correct. If so, the next step will be to collect data about habitat-types, vegetation-types, elements and species. In some cases the search for species is conducted in accordance with a predetermined list of indicator species but in other cases a more complete list of, for example vascular plants, is produced. Information about negative human impact, administrative status, management requirements etc. is sometimes recorded as well. During the fieldwork the surveyor also makes a preliminary assessment of the conservation values based on predetermined criteria. In this phase of the inventory the assessment is made in relation to a frame of reference consisting of a smaller number of sites on a local level. In a later phase this preliminary assessment may be adjusted in relation to a frame of reference consisting of a much larger number of sites on a regional or national level.

Compiling work. The compiling work consists of storing all collected data in a database, digitising the boundaries of all sites and storing this in a digital map database and presenting the inventory results in a report. The report could either be in the form of a catalogue consisting of database-generated form-sheets or a more exhaustive report where the sites, or a selection of sites, are described in detail. Collected data may also need to be rearranged in certain ways to be used in statistic analyses, gap analysis or for conservation priority purposes.

COMMENTS AND CONCLUSIONS

From the inventory-projects that have been carried out in Sweden, a number of conclusions can be drawn. These conclusions, connected to each phase of the work, will be presented below. Since the inventories have been carried out in Sweden the comments may reflect Swedish conditions. We will however try to present the conclusions in a more general way.

Introduction phase

• **Definition of site-type.** As earlier mentioned it is of great importance to define the site-type and the qualities that will be searched for in a relevant and correct way. For example, the virgin forest inventory conducted during the 1970's was criticised because, in accordance with the produced definition, it disqualified sites with traces of human impact without considering the biological qualities in a proper way. Forests untouched by man are very rare or absent in Sweden and in Europe as a whole, but the biological qualities of a so-called virgin forest can be found in forests with a moderate human impact as long as the forests contain old trees and coarse woody debris, are situated close to other valuable forest-sites or have never been clear-cut. During the woodland key-habitat inventory, where the surveyors largely searched for the same type of qualities, that particular mistake was avoided by using a subset of species that was considered to indicate high conservation values. Looking back it is now obvious that concepts such as "natural ecosystems" played a trick on the surveyors during the virgin forest inventory. Valuable wildlife areas and high biodiversity can be found in many different types of environments, also in places that have had a strong human impact for hundreds or, thousands of years.

➜ *Be aware of the consequences of vague or irrelevant definitions of site-types or biological qualities.*

➜ *The definitions can be used as a tool to avoid overlap or gaps in relation to other inventories that have been carried through.*

Inventory method. When producing an inventory method it is important to consider geographical conditions in terms of general features of the landscape, landuse history and the existing property-structure. Sweden is a vast country where conditions in the relatively densely populated southern part and the sparsely populated northern part are considerably different. In the southern part the landscape is strongly fragmented, has a long history of human landuse and an owner-structure where each property is relatively small. The size of a uniform forest stand is normally 0.5 - 10 hectares and there are often large differences between different stands. In the northern part on the other hand, the landscape consists of large areas of intermixed forests, wetlands or mountains, has a relatively short landuse history and is divided into relatively large properties. An inventory method with a stand-level perspective, like the woodland key habitat inventory, therefore works well in the southern part of Sweden but not so well in the northern part. With too strong a stand-level perspective there is a risk of missing high conservation values connected to larger forest-units. In the virgin forest inventory this problem was avoided since the method was strongly committed to the principle "the larger the better".

In mountainous areas, for example the Alps, the problems are of a slightly different type. In these regions large areas with almost no human impact alternate with patches used by man for millennia. If such regions are to be covered by an inventory the method has to be flexible and permit adjustments. In the Swedish wetland inventory the minimum area of sites to be covered by the inventory was changed from one or a few hectares in the southern part of the country to 50 or 100 hectares in the northern part. It is also possible (and sometimes desirable) to let the data collecting be based on remote sensing techniques to a larger extent.

➜ *Adjust the scale, the resolution and the minimum areas of the inventory to the landuse- and owner structure of the region.*

• **Database-structure.** According to our experiences, it is essential to connect the inventory method in general and the composing of the field-forms in particular, to a database structure. Development of the inventory method and development of a database structure must therefore take place simultaneously, preferably from the introduction phase onwards. This ensures that the collection of data is as uniform as possible. In the Swedish inventory of meadows and pastures the database structure was created after the fieldwork was finished. The original method was slightly altered in some regions but since no database structure existed, the changes were not made in a uniform way. These two factors led to an undesirable loss of homogeneity in the collected data set. If a database structure had been developed in an early phase of the inventory project for obligatory use these losses could have been avoided and the data entry would have worked more smoothly.

➜ *Develop a database structure in an early phase of the inventory project*

➜ *Let the surveyor do the data entry in close connection to the fieldwork*

➜ *Let the inventory project be centrally directed as far as possible. Regional adjustments should only be made in accordance with the existing database structure.*

• **Infrared aerial photographs.** A major part of the identification and delimitation of sites in the Swedish thematic inventories has been done by interpreting infrared aerial photographs. These photographs are very valuable tools when it comes to spotting, delimiting and to a certain extent also describing different sites.

When searching for open or semi-open wetland, semi-natural grasslands and deciduous woodlands the accuracy is very high. An experienced interpreter would probably find most of the sites containing these types of habitat. Coniferous forests and swamp woods are much more difficult to find. This can be explained mainly by the difficulties of identifying patches of coniferous forests of high conservation value in a landscape that to a very large extend also consists of coniferous forests but with a much lower value from a conservation point of view. In some cases the topography and other indirect indications may be of some help but that will only solve part of the problems.

According to our experience the use of infrared aerial photographs is not sufficient a tool when it comes to the assessment of nature conservation values. Some features such as old trees in a forest or a pasture, a well-grazed, semi-natural grassland or a wetland not affected by ditching could perfectly well be identified from aerial photographs and this can be used as guidelines when planning the fieldwork. The biological content - the amount of coarse woody debris in a forest, the insect fauna in a meadow or the fungi flora of a semi-natural pasture - can never be assessed by interpreting aerial photographs but only by a surveyor doing the fieldwork.

In some situations, as for example if the inventory is covering a very large-scale landscape (see discussion about mountainous landscape above), the assessment of the conservation value can be based on aerial photographs in a preliminary phase. The work effort is then reduced to an acceptable level (even if some fieldwork based on sampling has to be done) and it is also possible to get an overview of the landscape in a way that is difficult to achieve from fieldwork.

➜ *Use infrared aerial photographs if such photographs are available.*

➜ *Do not use aerial photographs for assessment of conservation values unless the inventory is covering a very large-scale landscape*

• **Existing knowledge.** It is very important that a thematic inventory aims to be as complete as possible.

The ambition should be to identify 100% of the site-type that is to be searched for in the region where the inventory takes place. It is therefore important that the search for sites is performed in an independent way and not directed by existing knowledge about individual sites. It is however an advantage to use sites with recognised high conservation values during the training to calibrate the personnel in terms of assessment of conservation values.

➜ *Do not let existing knowledge direct the search for sites.*

Fieldwork

• **Elements and structures.** The objectives of most inventories are to identify and delimit sites with high biodiversity, threatened by modern landuse. To conduct complete surveys for different groups of taxa is very expensive and the supply of experts is often not sufficient. The habitat demands of most species can be identified in terms of particular substrates, edaphic and climatic conditions or physical or biological structures. Dead wood of certain tree-species, size, decomposition and exposure are important features in a forest as are old hollow trees with rough bark and dead branches. In wetlands patches with running water can create valuable environments and in grasslands boulders may form important micro-habitats for mosses or lichens. All these phenomena are examples of elements that can be defined and quite easily taught to surveyors who are not experts in certain groups of species.

A semi-natural pasture can have patches of a short, intensely grazed vegetation next to patches of taller, less intensely grazed vegetation, thickets of thorny bushes, groves of broad-leaved trees and dead wood. These habitats may together form suitable environments for species that depend on different habitats during the completion of their life cycles. Such a pasture shows a certain structure and these structures can also be defined and taught to a surveyor. Thus by giving the surveyors a good training, the efficiency of an inventory can increase markedly.

➜ *Define elements and structures as tools for description and valuation of the sites.*

• **Indicator species.** During the fieldwork of all Swedish thematic inventories, species have been recorded. During the wetland inventory a more or less complete list of all vascular plants found on a site was made. In all the other thematic inventories species have been recorded according to a list of predetermined indicator-species. The indicator-species have been vascular plants, mosses, lichens or fungi that were considered to indicate high conservation values. Knowing the results of the inventories we can now conclude that the choice of indicator-species has, in some cases, led to systematic inaccuracies. Insects have in most cases not been used as indicator-species since they have been considered too difficult to recognise. Valuable insect sites, poor in mosses, lichens or vascular plants for natural reasons, have in some cases therefore been under valued or completely missed. For this reason there is a strong suspicion that many pine-forests and forests containing old birch and aspen have been under valued during the Swedish woodland key habitat inventory. During the ongoing woodland key habitat inventory in the Baltic States this inaccuracy has to some extent been corrected since the list of indicator-species contains a number of insects (Andersson *et al*. 1999).

Another example where the choice of indicator species has led to inaccuracies is the Swedish inventory of meadows and pastures. In this case the list of indicator-species consisted, almost exclusively of vascular plants. Since the inventory took place at a time where the largest threat seemed to be directed at intensely grazed grasslands most of the indicator species were weak competitors connected to grass-swards with low stature. For the assessment of conservation value the number of species belonging to this category found on a site was an important criteria. Many other organisms connected to grassland ecosystems are not favoured by large areas of intensely grazed grass-swords. Many insects are, for example, favoured by taller vegetation rich in shrubs and herbs with good supplies of pollen and nectar.

➜ *Develop lists of indicator-species as an additional tool for description and evaluation of the sites.*

➜ *Be aware of the fact that the choice of indicator-species may cause inaccuracies in the inventory result where site-types with a large number of easily identified and easily observed species may be over represented or overvalued.*

• **Quality-improving actions.** It is important that the inventory method can to some extent, reduce differences in qualification levels that may exist between different surveyors. A method that forces the surveyor to exercise a high level of thoroughness, without getting stuck in unnecessary details, is important and may act in this way. If the surveyor is aware of the fact that collected data will be stored in a database, this awareness normally contributes to a higher level of thoroughness. Furthermore, if the data entry is conducted by the surveyor another opportunity will arise for correction and completion of the data set.

A standardised special training in the inventory methodology for all surveyors is very important, not only to raise the level of knowledge among the workers but also to calibrate them to asses sites in a similar way. These courses must be practical and include visits to numerous sites. The wetland inventory, the meadows- and pasture inventory and the woodland key habitat inventory have all had such training courses.

To be able to evaluate and follow-up the inventories it is important to have information about all sites visited. Normally a large number of sites are visited that lack the qualities and values searched for, and are therefore disqualified. It is important also to keep a record of disqualified sites so that these will not be visited again later on for the same purpose. For the statistical evaluation it is also of interest to know the proportion of the pre-selected sites that actually contained values searched for.

➜ *Raise the level of thoroughness by letting the surveyor conduct the data entry.*

➜ *Organise special training for all surveyors to calibrate their assessments.*

➜ *Keep record of disqualified sites*.

Compiling work

• **Report.** The most important part of this phase is to compile the information collected during the inventory. It is of great importance that information is stored in databases, digitised and presented in a way that makes the information available for all stakeholders and interested parties. The traditional way of presenting the results of an inventory is to produce printed reports or catalogues and this is, no doubt, a good way of reaching a broad audience. Since the use of the Internet has become so popular new opportunities have arisen. The full result of the Swedish woodland key habitat inventory is for example presented on the webpage of the National Forestry Board under the title "the pearls of the forest" (http: //www.svo.se, http://192.165.43.9/). On this webpage the visitor can, with the aid of digital maps, find detailed information about individual sites. This is a very appetizing way of presenting information that otherwise may be considered difficult to access. Hopefully more inventory efforts will be presented in this way in the future.

➜ *Make the inventory result available and easily accessible to the public.*

How to use the results

The inventory results are primarily used as an information base for planning different actions in various administrative sectors of the society. During various development or exploitation projects it is possible to avoid negative impacts on valuable conservation sites by using the large amount of information collected during different inventories. New roads, railways, houses etc. can be located in the planning stage in areas where conflicts with conservation interests are minimised.

It is of course also obvious that the results from different inventories can be used when planning future conservation work. The assessments of conservation value made for different sites can act as a first criterion when directing and prioritising various conservation projects. It is however important to point out that some of the inventories, for example the inventory of meadows and pastures and the woodland key habitat inventory, have been conducted on a stand- or site level where the objective has been to delimit cores with high biodiversity. Therefore the inventory result can not automatically be translated into the borders of future nature reserves. To get an adequate base of information it is often necessary to conduct some kind of landscape analysis, which means that all geographical information from various inventories will be put together, so that concentrations of biodiversity hotspots can be localised. In other words the perspective has to be raised from stand/site level to landscape level. Not until such an analysis has been done it is possible to finally establish the priority order or borders of future reserves.

The large amount of information collected during the inventories has also been used by scientists (see for example Eriksson 1996, Eriksson 1998, Gustafsson 1999, Gustafsson & Ahlén 1996 and Söderström 1999). The scientific work has led to an increased ecological and biogeographical knowledge and this knowledge has in turn led to improvements in terms of better conservation work, better restoration work and better management plans.

Last but not least it is worth mentioning that the compiled results from an inventory may act as a very good guide for the public to experience valuable forests, wetlands or grasslands and thus lead to a raised level of awareness among people in general.

➜ *Use the inventory results when planning development projects.*

➜ *Use the inventory results when planning the conservation work.*

➜ *Be aware of the fact that normally the areas in need of protection are larger than the individual sites delimited in the inventories.*

➜ *Conduct landscape analyses in order to localise areas with high conservation priority*•

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