MOTH

more and better knowledge of less common habitats – a LIFE+ project

Why MOTH?

According to the European Union's Habitats Directive[1], the member states shall assure the conservation of natural habitat types of Community interest, as listed in Annex 1 of the Directive. Every six years, member states shall report on the measures taken to ensure the favourable conservation status of these habitat types, according to Article 17 of the Directive.

Addressing problems of assessment

However, the assessment of the conservation status of habitats is not always straightforward, not even in a country like Sweden, with its long tradition of national surveys. Forests have been monitored by the National Forest Inventery (NFI) since 1923, and other terrestrial habitats by the NILS program since 2003. Nevertheless, an evaluation of the Swedish Article 17 reporting showed various needs for improvement. Data deficiencies were prominent in a majority of seashore habitats, grassland habitats, and deciduous forests. The estimates of area, as well as variables describing functions and structures for these habitats, were reported with large uncertainty and low precision.

Therefore, a program for the development of a cost-effective national monitoring system, directly applicable for the implementation of the Habitats Directive, was launched in 2010 and run until 2014. It has been financed by EU's financial instrument LIFE+ and the Swedish Environmental Protection Agency. The program is called MOTH, an acronym for *Demonstration of an integrated North-European system for Monitoring Terrestrial Habitats* (LIFE08NAT/S/000264).

Designed for efficient data collection

The methods developed by MOTH are based on random sampling using a two-phase design, combining 1) remote sensing and 2) field sampling.

The remote sensing is done through manual interpretation of infra-red aerial photos. A skilled interpreter identifies various kinds of land cover (forests, grasslands, wetlands, shores, etc.), but also forms of land use, which are important for the assessment of a habitat's status. Field sampling is done by trained workers who provide more exact descriptions

In brief: According to the EU's Habitats Directive, member states shall conserve a large number of natural habitat types, and regularly report to EU on the progress. However, it is not always easy to assess the area and status of habitats. The purpose of the MOTH project has been to develop good methods for the mapping and survey of less common habitats, but they can used also for other habitats. MOTH's methods are based on a two-phase design. In the first phase, a preliminary assessment of habitat types is done using aerial photographs. In the second phase, field visits are directed towards selected sites where a final assessment is done.

1 Full name: Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

of all above but also supplementary data on species, dead wood etc.

For most habitats, the selection of interpretation points has been done through a *point-grid method*, and for seashore habitats, through a *line-intersect method*, which will be described in the following.

Pros and cons of two-phase design

The two-phase design will give precise estimates of the habitat areas given the total costs. Large areas are covered through relatively cheap remote sensing, while the costly field efforts are directed to areas where interesting habitat types are likely to be found. Also, habitat types which cannot be identified by remote sensing can be accurately classified in the field.

However, the design also presents some disadvantages. Intrinsic to the two-phase design is a complex variance analysis, and even more so when results from multiple monitoring programs are combined. Also, the aerial photos used for interpretation must be relatively new. During the MOTH project, most images had been taken one year prior to interpretation, at most five years.

In Sweden, the inventory has been performed in a very cost-effective way thanks to close cooperation with existing monitoring systems, but the methods are perfectly applicable without such support.

The first step of two-phase assessment is a general categorization of habitat types, made by aerial photo interpreters. The second step consists of field visits to a selection of points for detailed measurements and descriptions.

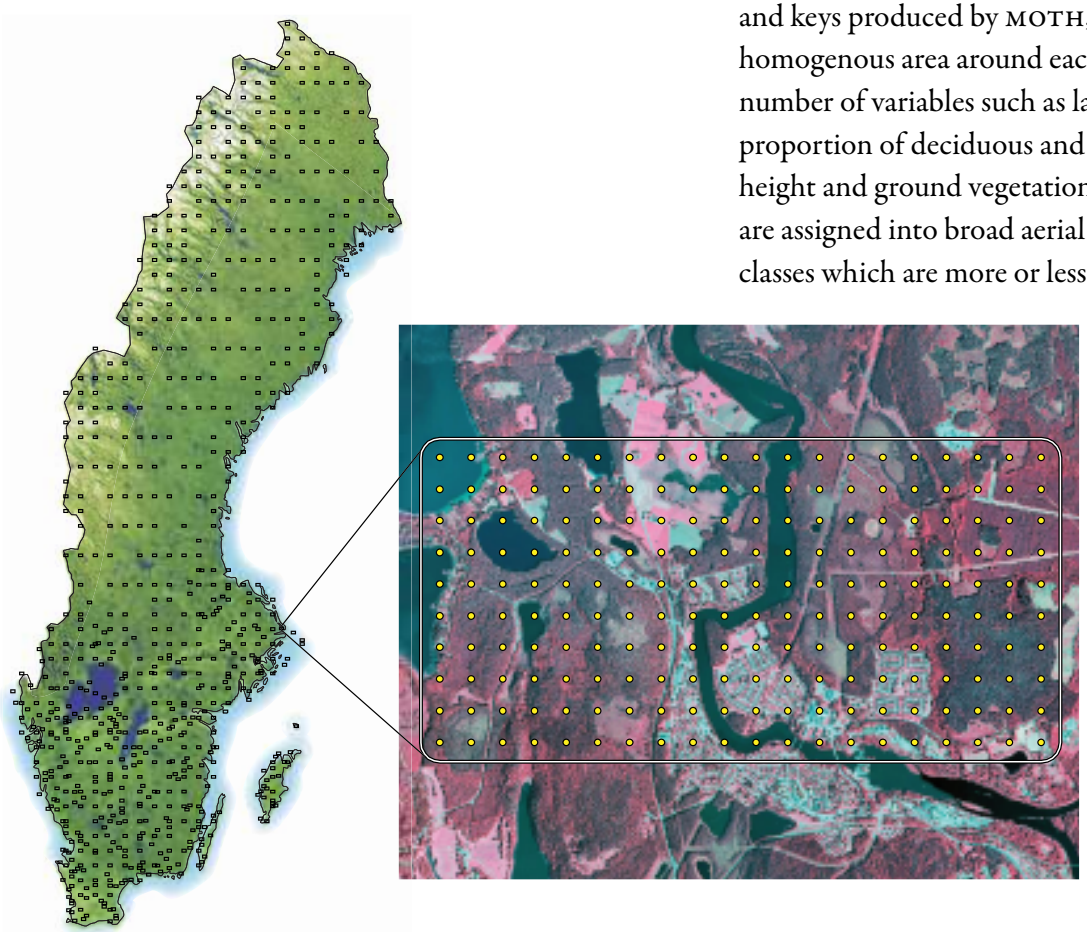
Terrestrial habitat inventory

For the inventory of terrestrial habitats, MOTH has made use of the already existing infrastructure of systematically distributed sampling units of NILS (National Inventory of Landscapes in Sweden). Since forests are closely followed by the Swedish National Forest Inventory (NFI), NILS has fewer units in northern Sweden, where coniferous forests dominate, and denser in the south, where there is more farming land. One fifth of all units are visited in the field and sampled every year. In order to gather sufficient data to assess deciduous hardwood forests and grasslands, MOTH has intensified the sampling effort in southern Sweden. In total, 565 sampling units have been surveyed.

The selection of points to analyse is made with a *point-grid method*.

Phase 1: Interpretation of aerial images

On each infra-red image representing a sampling unit, a grid of 200 points is superposed. Using the manuals and keys produced by MOTH, the interpreter defines a homogenous area around each point and scrutinises a number of variables such as land use, tree cover, proportion of deciduous and coniferous trees, tree height and ground vegetation. From this, grid points are assigned into broad aerial interpretation (AI) classes which are more or less likely to include habitats



The map of Sweden shows the 565 sample units analysed by MOTH during 2010–2013. Enlarged is an infra-red image of one of these units with the 5 km x 2,5 km point-grid superposed.

Grid points superposed on an infra-red image. The point in the middle is classified as located in a wooded pasture, a class which is given highest priority for field visits since it is a habitat of community interest. The others are located on arable land with low priority.

of community interest, listed in the EU's Habitats Directive. Each year, interpreters study images and field data from the year before, the feed-back further improving the quality of their assessments.

A given proportion of each AI class is selected for field visit. The exact points in each class chosen for field visit are selected in a random manner. While AI classes that enclose less common habitat types are given highest priority, classes with habitat types which are well covered by NILS and NFI are given lower priority. Points in lakes and watercourses are never visited, nor are points where natural qualities have been lost. During the project, 5 976 points have been selected to be visited in field.

Phase 2: Field inventory

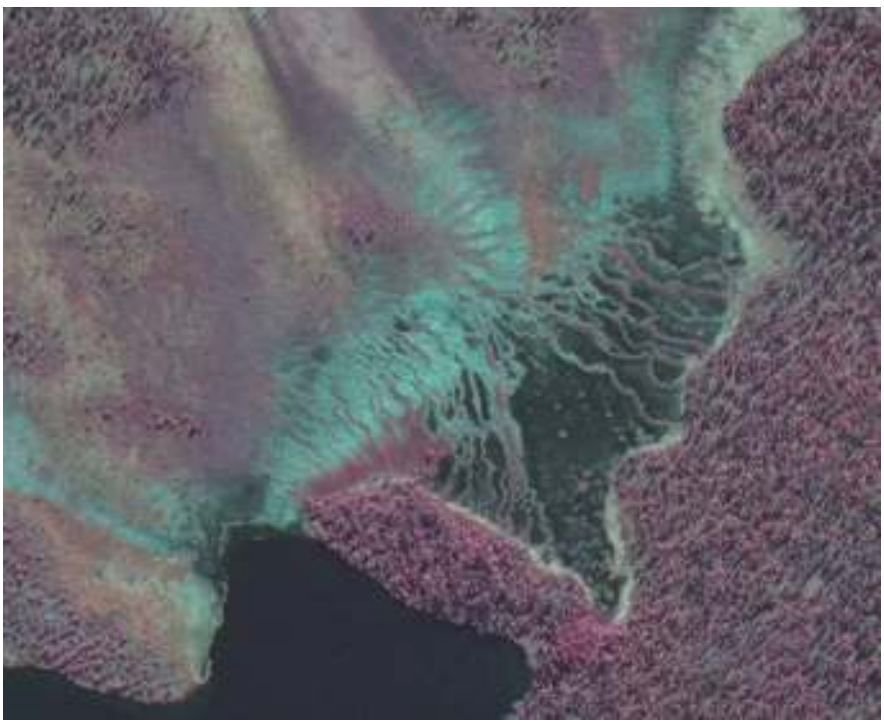
The field work has been performed by the staff of NILS from the end of May till the end of September. Helicopters have been used for transportation to the most remote parts of northern Sweden. Once in the field, the workers locate the selected point with a gps and

Field staff gathers detailed data from a plot with a radius of 10 metres (the innermost red area) centered on the grid point which has been classified by the aerial interpreter. In order to describe the surroundings of the plot an area of up to 20 metres from the point (outer red area) is taken into consideration.

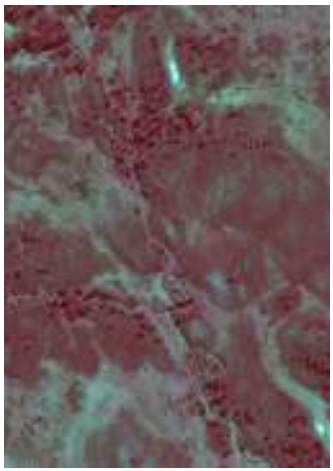
The field staff must be comfortable with working long days outdoors in almost any weather.

use it as a centre for a plot with a radius of 10 metres. Inside the plot, habitats of community interest are registered, and detailed data is sampled on vegetation, humidity, soil type and slope. For valuable documentation, photos are taken in four directions from the centre point. An area up to 20 metres from the centre point is taken into consideration for a more general description of the habitat, including the cover, age, height, stem density and basal area of the tree layer. Notions on land use are also gathered from the 20 metres plot. All the data is continuously registered in handheld computers and is transferred digitally to the office on a daily basis.

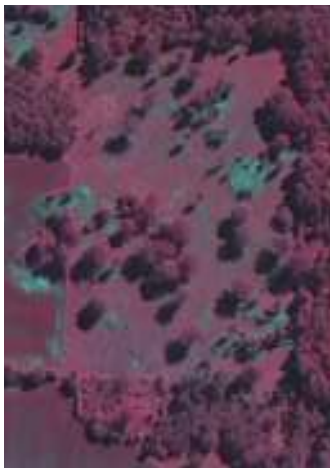
In brief: In the point-grid method, a grid of 200 points is superposed on an infra-red aerial image. Interpreters scrutinise the area around each point and make a general classification of habitat types. Depending on the kinds of habitat detected, points are placed in interpretation classes with different priorities for field visits. From each class, a certain number of points are selected for field visits and a more detailed description of habitat types. The method is suitable for inventories of habitat types which are dispersed all over the landscape.



Aapa mires (habitat code 7310) consist of several connected types of mire, both forested and open bogs and fens. In the complexes, dry linear hummocks alternate with wet hollows and pools in a characteristic pattern easily detected by aerial interpreters.



Alpine heath (habitat code 4060) as viewed by the field worker and the aerial interpreter, respectively. The vegetation is dominated by subshrubs and willows, sedges and narrowleaved grasses.



Wooded pasture (habitat code 9070). The land shall have been grazed for at least 25 years and shall include old or dead trees. The ground vegetation shall be characterised by species typical for grazed land.

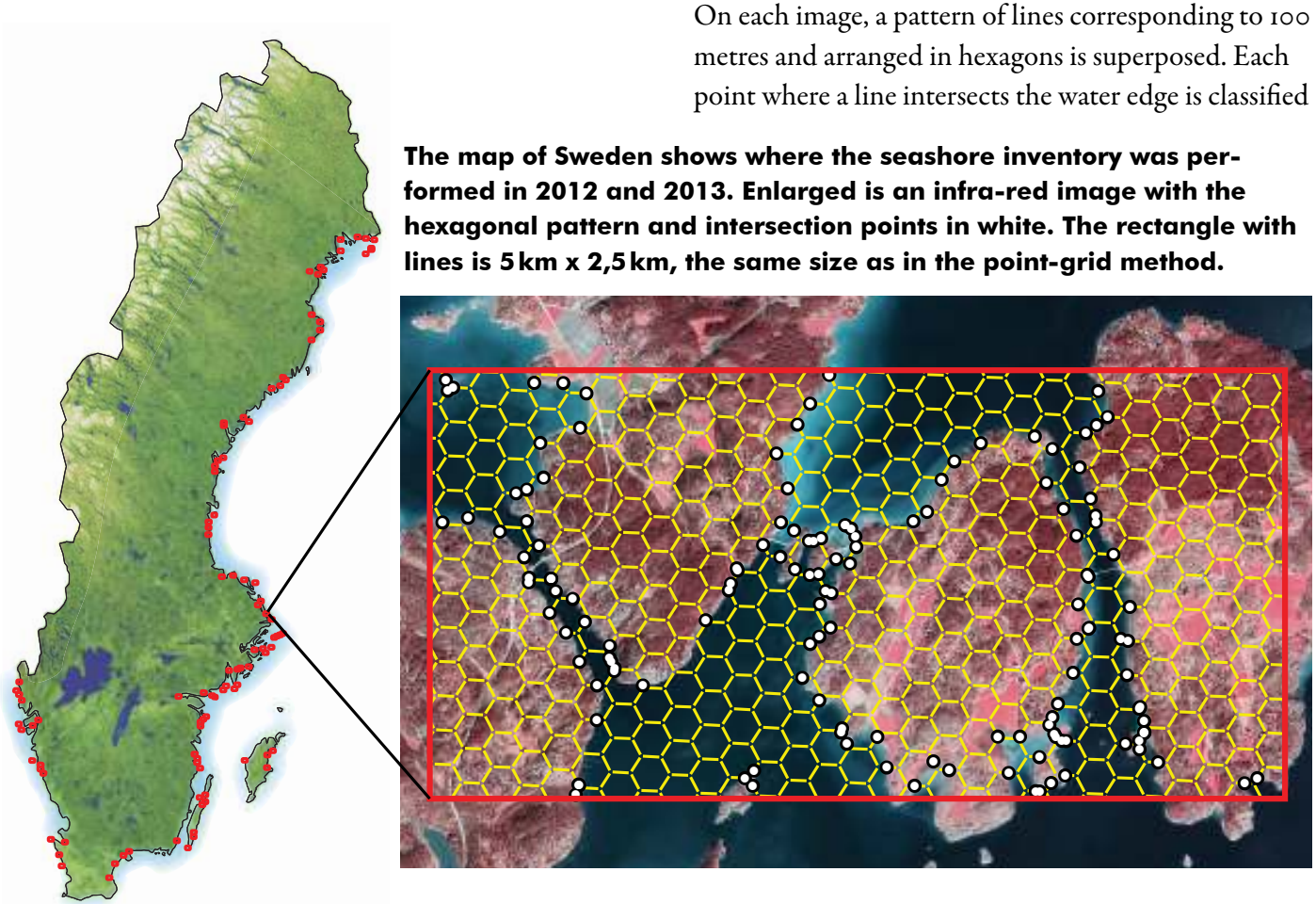
Fennoscandian deciduous swamp wood (habitat code 9080). In northern Sweden, this habitat is dominated by grey alder, downy birch and aspen, further south by black alder and ash. Ground water level is high and floodings usually occur yearly.

Seashore inventory

The habitats of the coast are different from those of the interior since their occurrence is easily predictable to the linear borderland between sea and land. In MOTH, a *line-intersect method* has been developed for the monitoring of such habitats. It is not based on the sample units of NILS, which are too widely dispersed along the coast, but on the 5x5 km squares of the Swedish National Land Survey. A sample has been created consisting of 250 squares, evenly distributed along the coast, including islands. Every year, one fifth are analysed. MOTH's seashore inventory is the first survey of the entire Swedish coastline involving both remote sensing and field inventories.

Phase 1: Interpretation of aerial images

Just like the point-grid method, the line-intersect method is based on a two-phase design where the first phase is an interpretation of infra-red aerial images. On each image, a pattern of lines corresponding to 100 metres and arranged in hexagons is superposed. Each point where a line intersects the water edge is classified



The map of Sweden shows where the seashore inventory was performed in 2012 and 2013. Enlarged is an infra-red image with the hexagonal pattern and intersection points in white. The rectangle with lines is 5 km x 2,5 km, the same size as in the point-grid method.

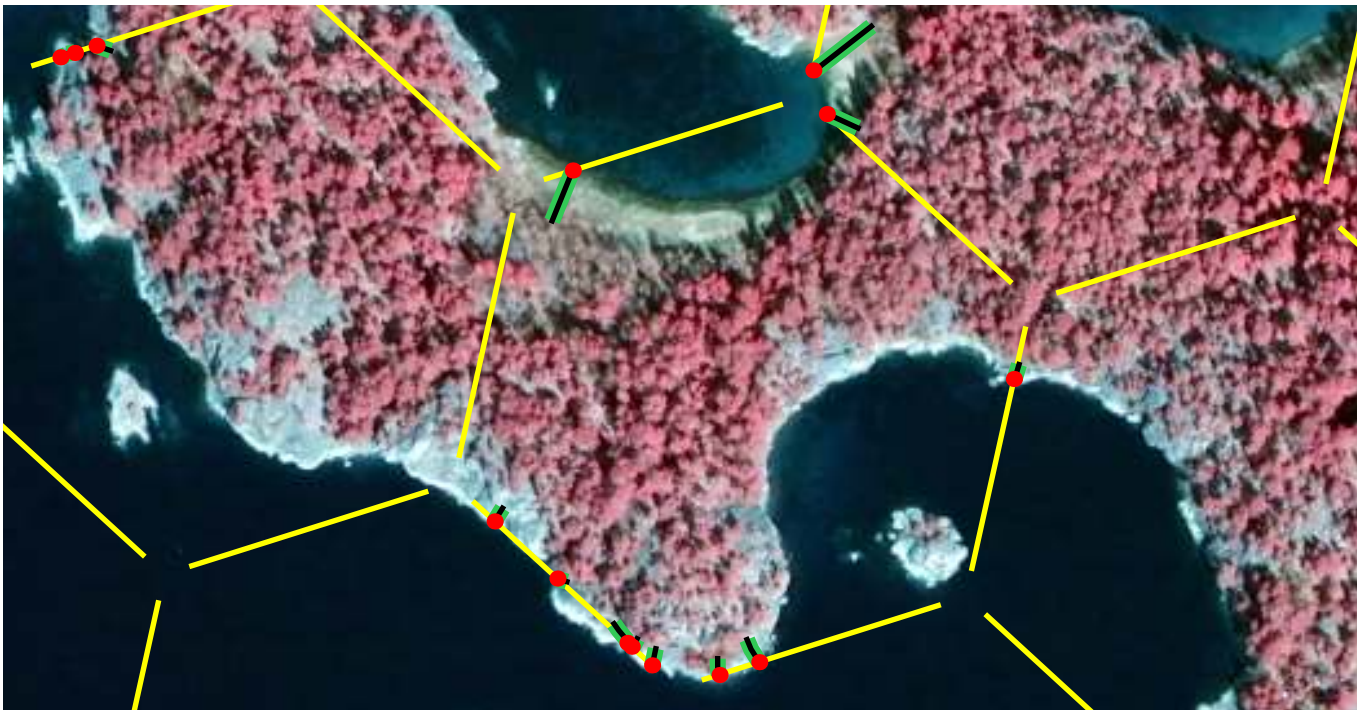
into one of five broad substrate-based shore-type classes: cliffs, boulder/gravel, sand, coastal meadow or constructions. Also, an interpretation area is placed up along the shore from the point, at right angle to the contour. A range of vegetation coverage variables are registered from this area, and a classification into sub-types is done if there are sand dunes, land upheaval forest, high cliffs or reeds by the shore, of if it is located on a treeless islet. From each class, a number of points is randomly selected for field visits. About 230 seashore points have been visited each year.

Phase 2: Field inventory

The field work has been performed by personnel from the terrestrial inventory who have been given specific training. Once in the field, the field workers locate each chosen line-intersect point with a gps. From

Field inventory on cliff shore.

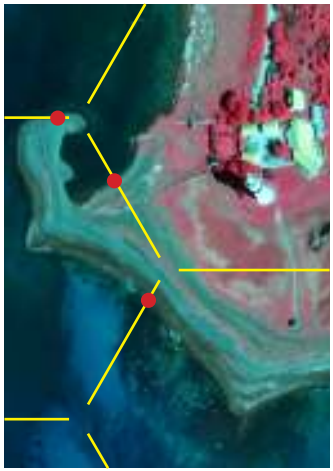
The aerial image shows how the interpretation areas are placed from the line intersection points at right angle to the shore contour.



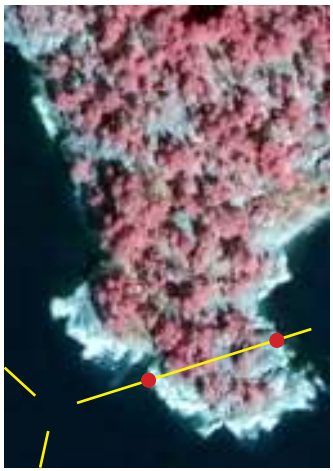
there, they place a line at right angle to the contour, mainly up along the shore but sometimes also into the water, depending on current water level. This line is the middle of a transect which is ten metres wide. The area is divided into different zones (hydro-, geo- and supralittoral) based on indicator species and structures. If habitats of community interest are found, they are classified and their length along the line is noted. A number of variables are recorded, including land use, plant species and the composition of drift lines (both garbage and natural). If there are dunes, land upheaval forests etc. by the shore, data is collected also about these habitats.

In brief: The line-intersect method is used to select the seashores to be analysed. A set of lines arranged in a hexagonal pattern is superposed on an aerial image. At each point where a line intersects the water edge, seashore characteristics are interpreted. The interpreter scrutinises a narrow area drawn at right angle up along the seashore and makes a general classification according to substrate and some other criteria. From each class, a number of points are chosen for field visits and a detailed description of habitat types. The method is suitable for the inventory of linear habitat types.

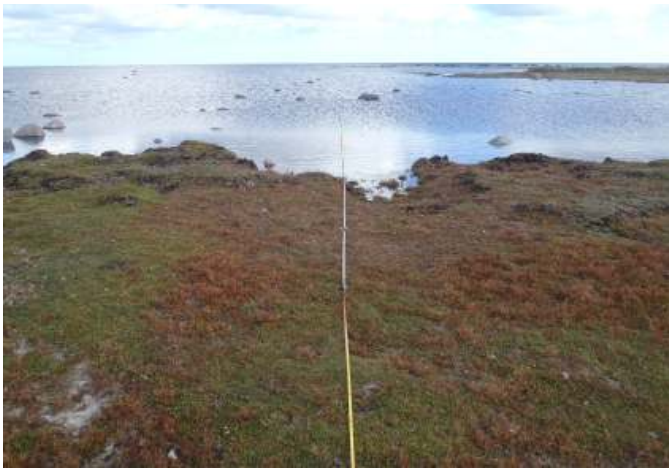
Above: sea kale (*Crambe maritima*) is one of the species registered in the seashore inventory. Right: in MOTH, drift lines are registered also on constructed shores (here a road fill), but their conservation status is low.

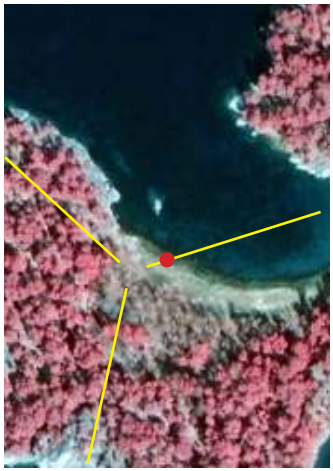


Stony banks (habitat code 1220). The vegetation may include herbs like *Cakile maritima* and *Spergularia marina*, but may also be dominated by grasses, subshrubs, mosses or lichens, depending on the exposure to wind and waves.



Sea cliffs (habitat code 1230). Cliffs are often completely bare, but in crevices where organic matter has accumulated, grass, subshrubs, herbs and even trees and bushes can be found.





Boreal Baltic coastal meadows (habitat code 1630). Coastal meadows are formed by a dense vegetation of mostly perennial plants. They can be found in sheltered locations where fine sediments have accumulated.

Classification of habitat types

In the MOTH project, detailed manuals have been produced for the classification of the natural habitat types listed in EU's Habitats Directive. All habitat types have to fulfil certain criteria of naturalness. In order to be registered, they must also cover a minimum area. Habitat types are then classified according to strict criteria, such as "richness" and "poorness". All of these criteria have to be adapted to regional conditions. In Sweden, we have chosen to define them in the following ways.

Criteria of naturalness

The criteria of naturalness differ between habitat types. Forests, wetlands and shores should only be mildly influenced by human activities. Forests obviously affected by recent cuttings, ditched wetlands, and shores along regulated lakes are excluded. By contrast, the biological values of pastures and meadows are due to long use with certain practices, so these habitats should neither have been abandoned too long nor be affected by fertilizing or ploughing. Constructed areas are always excluded.

***Dryas octopetala* is an indicator of mineral-rich conditions in the alpine zone.**

Minimum area required

The area of the habitat must reach a certain limit in order to be registered. Forests must cover at least 0.25 hectares, while the limit for wetlands and grasslands is set to 0.1 hectares. Springs are always registered. Special criteria apply to screes and shores.

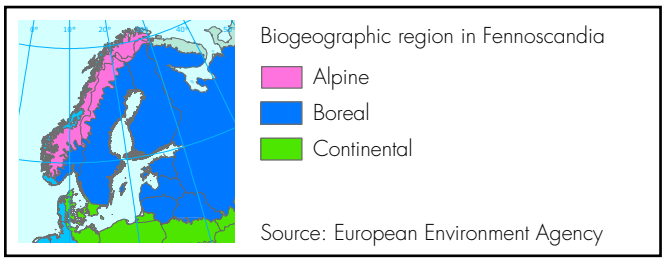
Rich and poor habitats

"Richness" and "poorness" have different meanings in different habitats. Rich forests are rich in nutrients such as phosphates and nitrates. In MOTH, this is assessed using indicator species defined by the National Forest Inventory. By contrast, rich fens and grasslands are usually poor in nutrients but rich in minerals, in particular calcium. This kind of richness is assessed using lists of indicator species produced by MOTH. Each species equals a point, or sometimes 1/3, for species which are less strictly indicative. When the sum reaches 3 points, the habitat is classified as rich.

In brief: When classifying habitat types, it is important to assess their naturalness and whether they are influenced by rich or poor conditions. A minimum area must be covered. Criteria must be defined according to regional circumstances.

MOTH makes a difference

The methods of the MOTH project are designed in such a way that even relatively rare habitat types will be registered in many plots. The more units included in a sample, the better the estimates of the variable studied. Complementing NFI and NILS with data from MOTH gives an important contribution to the assessment of the conservation status of the habitat types listed in the Habitats Directive. Here are some examples:

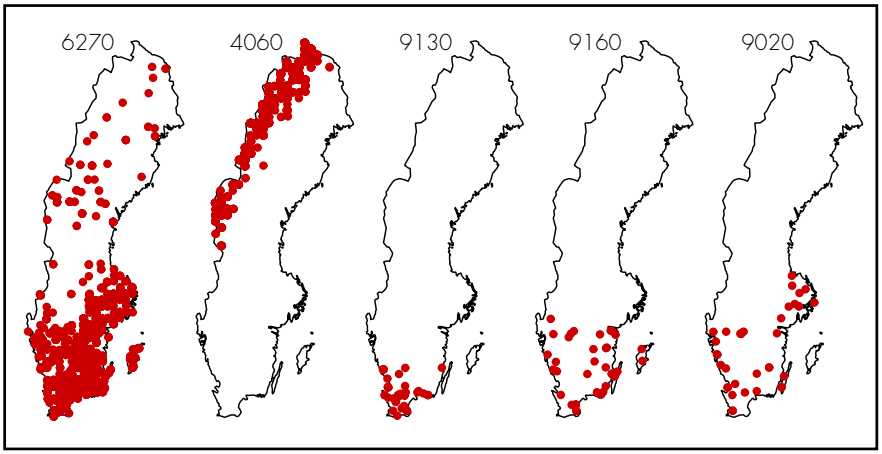


Area and range

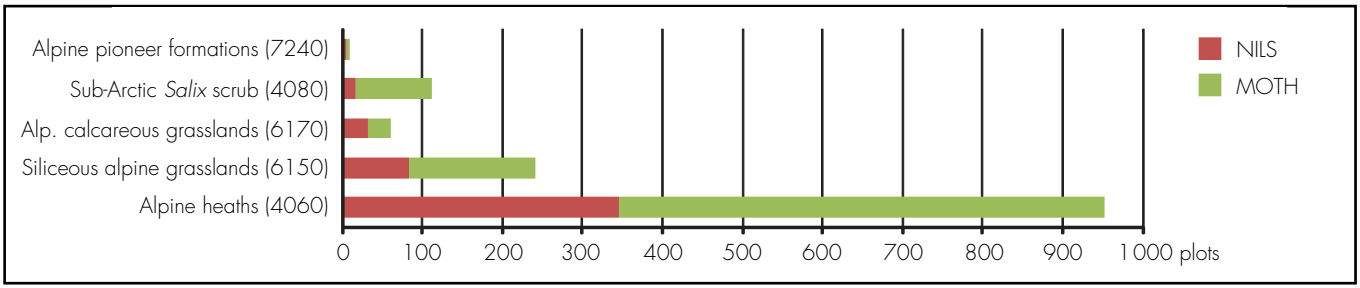
When assessing the area of a habitat type, about 30 randomly selected plots are needed for an approximation and about 100 plots for a reliable estimate. A smaller number of plots can nevertheless be useful in order to analyse other important aspects of the conservation status of a habitat type, such as its range (see maps below).

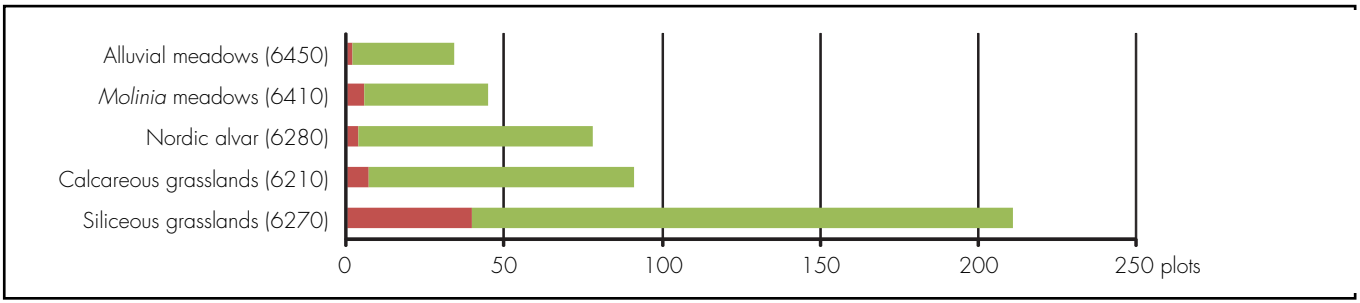
The surveillance of the conservation status of the habitats is, however, not done only per country but also per biogeographic region, and then a sample of the mentioned size is needed for each region. Sweden is included in three regions (see map above): alpine (ca 8 million ha), boreal (ca 30 million ha) and continental (ca 3 million ha). For really rare habitat types it can be difficult to create sufficiently large samples even for an approximate areal estimate, especially in the continental region.

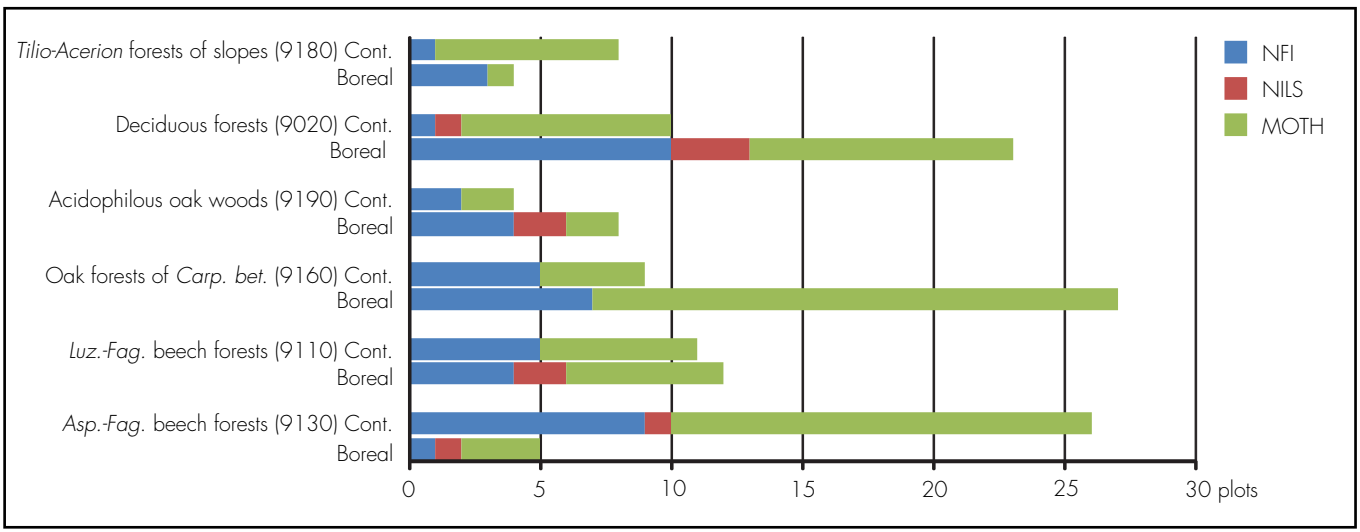
The figures on page 14 show the number of plots for different Swedish habitat types which have been provided by the three national Swedish inventories. Thanks to MOTH, we can now make good estimates for



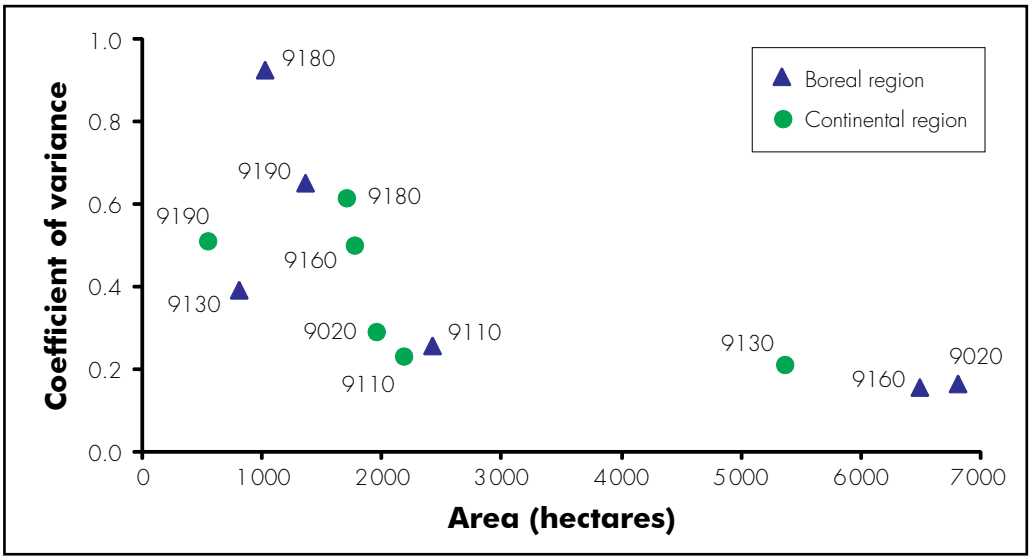
Maps of the range of five Swedish habitat types: dry to mesic grasslands (6270), alpine and boreal heaths (4060), *Asperulo-Fagetum* beech forests (9130), Sub-Atlantic oak forests (9160) and Fennoscandian deciduous forests (9020). The maps are based on combined data from the three Swedish national inventories, including MOTH.







The figures show the number of plots classified as belonging to different habitat types in the three national Swedish inventories. At the top are some alpine habitat types. MOTH gives priority to less common habitat types and produces useful data on them, but also hits many occurrences of alpine heaths since many habitats occur intermixed with the heath. In the middle are some grassland types, where the contribution of MOTH makes a large difference. At the bottom are some deciduous hardwood forest types in the continental and boreal regions. Data from the National Forest Inventory (NFI) and NILS are from five years (2008–2012), which equals a normal inventory cycle, while the MOTH data has been gathered during the four field seasons of the project (2010–2013).



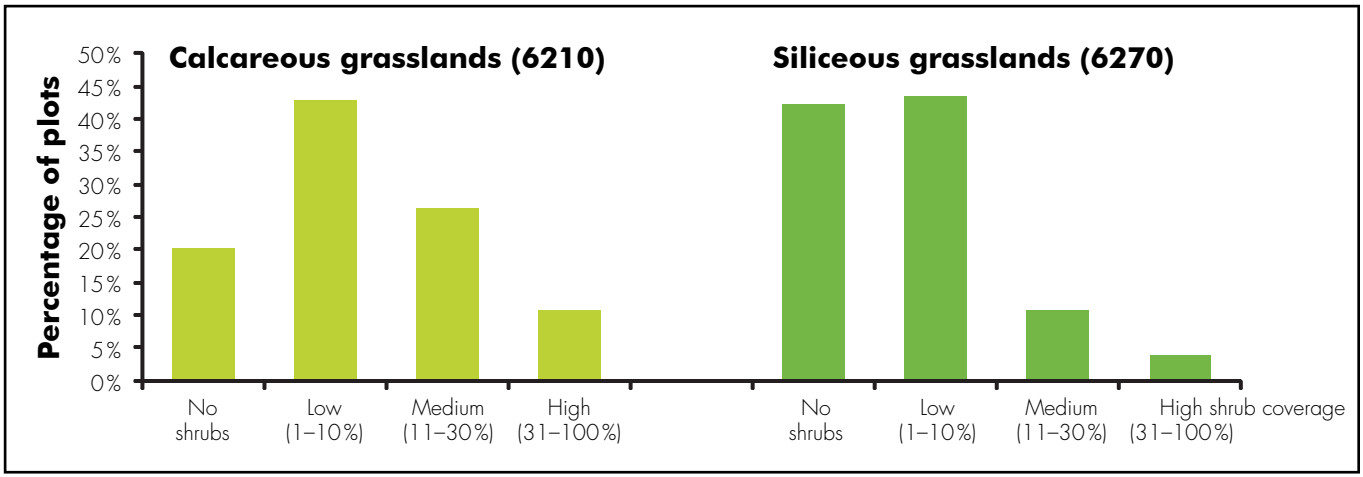
The figure shows the areas for the same deciduous hardwood forest types as in the last figure, in the boreal region and the continental region, based on combined data from NFI, NILS and MOTH. A lower coefficient of variance suggests a better areal estimate.

several alpine habitat types. MOTH has also provided more information on grasslands and deciduous forests. However, when the sample is small, such as for deciduous hardwood forests, areal estimates are unreliable (figure above). It may then be better to pool data, either per habitat type or for the group as a whole.

Species occurrences

For some variables, for example the occurrence of a certain species in a specific habitat, many more plots may be needed in order to make good estimates, since the species may not be found in a sufficient number of plots. Good estimates of single species' occurrences are most readily made for species which are relatively common in the habitat. Also the field methodology will influence the probability of registration of a species. In MOTH, occurrences of single species are registered as well as coverage of functional groups such as bushes and large field-layer species.

***Armeria maritima* is one of the plant species which is registered in the shore inventory.**

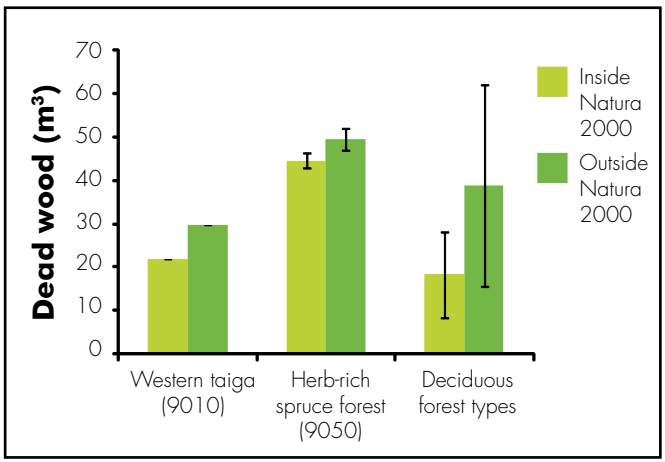


The percentage of plots in different classes of shrub coverage for two grassland habitat types.

Structures and functions

The concept of favourable conservation status also implies that important structures and functions are present in the habitat. MOTH gathers information on shrub coverage, which can be used to measure overgrowth. The figure above shows the shrub coverage in two grassland habitats. In most cases, the degree of overgrowth is low in both habitat types, but the amount of plots that suffer medium to high shrub coverage is higher in calcareous grasslands.

In forests, the amount of dead wood is a factor of large importance for many organisms, useful for measuring conditions for biodiversity. There is more dead wood in older forests than in younger production forests, but MOTH data shows that there are also differences between protected and non-protected forests. For the habitat type "western taiga" (9010), there is more dead wood in forests inside Natura 2000 sites (i. e. nature reserves and other kinds of protected forests) than outside. The same seems to be true of herb-rich spruce forests and deciduous hardwood forests, but the results are not as clear.



The amount of dead wood in forest habitat types is on average higher inside Natura 2000 areas than outside (mean ± 1 standard error). Note that both classes only include forests which fulfil the criteria of naturalness.

Shore inventory

Already after two seasons of two-phase assessments with a line-intersect method, MOTH has produced better data on the habitat types of the Swedish coast. Based on interpretation of aerial images, we assess the total shore length, including all islands and islets, to be about 41 000 km. Shores with rocks, boulders and gravel dominate (69 % together), while ca 8 % are sandy shores and 15 % shores with finer sediments and vegetation.

Shore field worker and means of transportation.

Exploited shores

About 8 % of the Swedish shoreline is constructed for some purpose or another. Shores can also be located so close to houses, roads, power lines and other kinds of exploitation that the biodiversity of nesting birds, pollinating insects etc. might be affected. Using buffer zones of exploitation we see that this applies to 21 % of the Swedish shore line (see table below). The degree of exploitation is higher in sheltered locations with sandy beaches and coastal meadows than in locations which are more exposed to waves and consist of larger coarse substrate like rocks, boulders or gravel.

Coastal habitat types

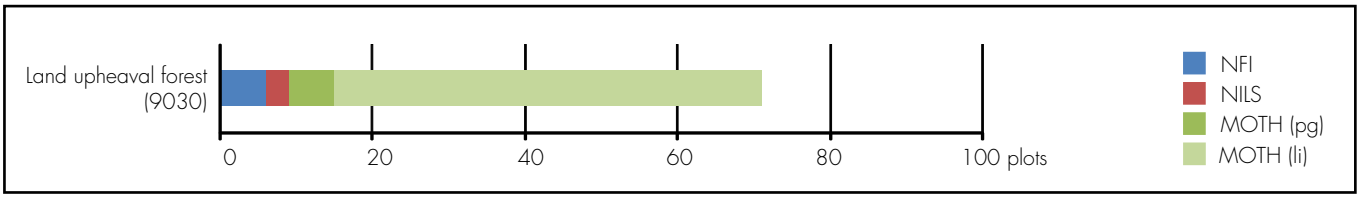
The total area of Swedish shores is assessed to 64000 ha. Of this, 37% is located on the mainland, 54 % on islands larger than 0.1 ha and 9 % on smaller islets and skerries. Areas of natural habitat types on or close to shores are shown in the table below.

Length of substrate based seashore types in Sweden and proportion affected by exploitation. The data is based on aerial image interpretation of 100 MOTH plots during 2012 and 2013.

Seashore type (substrate)	Length (km)	% of length	Proportion exploited
Cliff/bedrock	17095	42%	6%
Boulder/gravel	11018	27%	19%
Sand	3313	8%	26%
Meadow/wetland	6191	15%	23%
Constructed	3357	8%	100%
Total	**40975**	**100%**	**21%**

Estimated areas in Sweden for some habitat types listed in EU's Habitats Directive. The estimates are based on data from 100 MOTH plots investigated in the field 2012 and 2013.

Habitat type (code)	Area (ha)
Sea cliffs (1230)	24200
Salt meadows (1330)	1500
Baltic coastal meadows (1630)	9900
Baltic sandy beaches (1640)	3400
Dune habitats (2100)	4800
Land up-heaval forest (9030)	17100



The line-intersect method (li) which has been used for MOTH's seashore inventory during two field seasons has rendered the registration of far more plots with land upheaval forest than in the other two inventories during five years. The point-grid (pg) method has also rendered some plots.

Habitat types above the shore

MOTH's seashore inventory is primarily directed to the shore proper, which includes the upper zone influenced by stormal waves and splash. However, where habitat types of community interest occur just above the shore, the inventory has been expanded to include them. MOTH has therefore rendered better knowledge on for example land upheaval forests. Neither of the other two Swedish national inventories hits this habitat to a sufficient extent, but the situation has now improved significantly thanks to data gathered during only two seasons of MOTH seashore inventory. We now know that there are about 17 000 hectares of land upheaval forests with the natural qualities required for habitats of community interest.

Land upheaval forest is the last successional stage of the shores of the Baltic sea. The lower part is often dominated by grey alder and rowan, the higher part by spruce and pine. Forestry is normally introduced ultimately, leading to a loss of natural qualities. Sometimes, the timber has to be transported on barges.

MOTH is ended but not over

The experiences from the MOTH project shows that information can be gathered on valuable nature in a cost-effective way by combining remote sensing and field inventory of a randomly selected sample of control points, if possible in cooperation with existing national inventories. Remote sensing alone is not enough, since it is rarely possible to describe differences in species composition or detect or even assess the criteria of naturalness in a reliable way. The final classification must be done in the field. The methods developed by MOTH, based on a two-phase design, enables the relatively expensive field visits to be directed towards interesting areas. The methods are not only applicable to habitat types of community interest but can be used for any kinds of habitat.

Reliable estimates

In Sweden, MOTH data on the range and area of habitats were used for the Article 17-report in 2013. A continuous use of MOTH data will enable reliable comparisons of the conservation status of habitat types inside and outside protected areas, and thus of the contribution of the Natura 2000 network. Field methods used in MOTH are developed to be coherent to those in NFI and NILS, so that combined data analyses can be made. Among the status variables which can be analysed are:

- shrub coverage as a measure of overgrowth
- coverage of light-demanding plants
- occurrence of invasive species
- vegetation height as a measure of grazing intensity
- composition of drift material along the shore

MOTH data is already in use for an evaluation of Swedish environmental goals.

Useful also for others

MOTH has been focused on habitats of Northern Europe. However, the methods which we have developed can be applied to any environment, after adjusting the criteria of naturalness and the definitions of habitat types to regional conditions. A close cooperation with existing national inventories has been a great advantage for MOTH, but is no requirement. MOTH can be run as an independent monitoring system.

Comparisons between member states would be greatly facilitated by a wider application of the MOTH methods.

Further development

The experiences from the MOTH project has also rendered new ideas. For example, the line-intersect method could be used for monitoring shores along lakes and watercourses, but also alpine environments which often are linearly developed along a slope.

All publications and other documents developed by MOTH are available on the project web site, which will be active until 2020.

Web site: <http://www.slu.se/moth>

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This publication is a layman's report. For the Swedish-speaking public, there is a similar report in Swedish.

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