Habitat Inventory by Aerial Photo Interpretation in MOTH – Terrestrial and Seashore Inventory

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1 Introduction

Biodiversity is decreasing globally, throughout Europe as well as nationally in Sweden, largely due to anthropogenic activities. One legislative instrument with the objective to slow this process and to monitor biodiversity loss is the EU's Habitat and Species Directive (Council Directive 92/43/EEC) (hereafter referred to as the directive). All member states of the EU have though the directive a responsibility to protect, preserve and improve the conservation status of a number of natural habitats and species considered important to biodiversity. By adopting this directive member states are (amongst other things) obliged to report, in accordance with Article 17, on the distribution and conservation status of the species and habitats listed within the directive every six years. For such reporting to be possible – likewise an obligation according to Article 11 - a state needs to perform ongoing monitoring of listed species and habitats.

The conservation status of species and habitats listed in the directive is a good indicator of the status of Sweden's nature at large (Eide, 2014). The overall objective of the directive is favourable conservation status which can be described as the situation where a habitat type or species is thriving and with good prospects to do so in the future. The evaluation of a habitat's conservation status involves assessment of distribution area, coverage, quality of structures and functions, and a description of future prospects (Evans and Arvela, 2011). Data to answer these questions has for many Annex 1 habitats been insufficient, particularly for seashore, alpine, grassland and broad-leaved forest habitats. In the latest report delivered to the EU in 2013, Sweden presented separate assessments were for 169 species and 89 habitats (Eide 2014). Data from numerous sources, including MOTH, were used in this reporting.

The use of remote sensing techniques, such as aerial photo interpretation, have large potential in identifying areas with high probability of containing target Annex 1 habitat. However, it is important to understand that there is not a 1:1 relationship between most aerial photo interpreted habitat codes and Annex 1 habitats, as the latter also need to meet criteria that can only be identified in the field. To differentiate the Annex 1 field definition from the code used in aerial photo interpretation we use the prefix **AI** for the aerial photo interpretation code in this report.

The following text describes the methodology associated with the aerial photo interpretation of terrestrial and seashore habitats in Sweden in the MOTH project during 2010-2013. While all habitats inventoried by MOTH are terrestrial we refer to the inventory of coastal habitats as the *seashore habitat inventory* and inventory of remaining "inland" habitats as *terrestrial habitat inventory*. The seashore habitat inventory involves a different methodology and therefore receives separate subheadings in this text, although certain chapters and sections, regarding aerial photo interpretation in general, can be applied to both.

1.1 The MOTH project

Despite the fact that Sweden has a tradition of national surveys, the assessment of conservation status of Annex 1 habitats is not straightforward. Forests have been monitored since 1923 by the National Forest Inventory (NFI) and other terrestrial habitats by the National Inventory of Landscapes in Sweden (NILS) and National Survey of Meadows and Pastures (ÄoB) since 2003. These existing nation-wide monitoring programs are able to contribute to the habitat assessment for a large number of terrestrial habitats; however due to restrictions in the sampling design, they can only deliver sufficient data on relatively common habitat types. Data has been deficient for the majority of the seashore habitats, grassland and alpine habitats as well as for deciduous forest. These habitat types can be described as sparse and/or having a restricted distribution. To capture these habitats intensified and altered sampling methods have been required.

When it comes to seashore habitats, comprehensive field studies of the Swedish coastal shoreline have not been achieved in recent years. The most extensive study was carried out in 1969 by the Department of Planning (Wennberg and Lindblad 2006). The main aim of that survey was to map the substrates of the coast of the Swedish mainland and larger islands for recreational area planning purposes, and was performed by walking the shoreline. However, the survey did not include islands in archipelagos and was not comprehensive due to difficulties in digitizing all the notes and diaries from this time. Several studies of the Swedish coastline using remote sensing and GIS based modelling have been performed (Wennberg and Lindblad 2006, Törnqvist and Engdahl 2010) and some field-based vegetation surveys has been made by County Administration Boards in some areas. However, MOTH Seashore inventory is the first nationwide survey of the Swedish coastline involving both remote sensing and field-based stages.

For both terrestrial and seashore survey the aim of the MOTH project is to develop and demonstrate an inventory scheme for Annex I habitats using two-phase sampling. Phase one consists of sampling by remote sensing (aerial photo interpretation) and phase two consist of field sampling. This inventory should be able to record data in all terrestrial habitat types, i.e. grasslands, forests, wetlands and alpine, as well as seashore habitats and have the potential to specifically target habitats were existing data sources are insufficient. This manual describes the working process of phase one – aerial photo interpretation – of both terrestrial and seashore habitats, which should be regarded as completely separate inventories.

1.2 Sampling design

In order to capture the sparse habitats that NILS and NFI do not include to a statistically satisfying degree, intensified sampling is required. For this sampling to be cost-effective it was is necessary to perform it in two phases. The first phase comprises an intense sampling effort by remote sensing. The results of the remote sensing directs the efforts in the second phase, the more costly field sampling, to points with higher probability of containing targeted habitats (Ståhl *et al.* 2007). This has been done in MOTH terrestrial inventory by sampling with grid-point clusters within the NILS grid and selecting interesting points for field sampling.

Seashore habitats on the other hand, are linear landscape elements. They have an unusual distribution pattern of and are usually long and narrow in shape, with relatively low total coverage. They are however, easy to locate as they are restricted to the coastline. An effective method to sample linear features is line-intersect sampling. NILS uses line-intersect sampling in the field to sample forest edges, ditches, pathways, and fences allowing estimates of the length of these features in the landscape. MOTH has implemented a novel sampling design that uses a line-intersect sampling in the remote sensing of the first phase in the Seashore Inventory.

The two-phase design used in MOTH makes pre-fieldwork prioritizing possible. Target habitats where data is lacking from other National sources can be given high priority. Furthermore, MOTH has used the same field sampling methods (in terrestrial habitat inventory) in phase two as in NILS and the Swedish NFI and thereby making it easier to combine the estimates from these monitoring programs.

1.2.2 Terrestrial habitat inventory

MOTH has used the general the sampling grid defined by NILS that has been surveyed since 2003. The motivation for using the same infrastructure was to reduce costs for aerial photos, field staff, field staff education, field method development and equipment, data acquisition and database development. The NILS sampling design consists of a random systematic grid of 631 permanent 5x5 km landscape units, stratified into ten regions, covering the whole Swedish land base (Fig. 1). The sampling units are surveyed by the NILS program in five-year rotations to provide data about land-use conditions and landscape change (Ståhl *et al.* 2011).

In MOTH, a grid of 200 points is overlain each sampling unit in the NILS grid (Fig. 1). The point-grid covers a 2, 5 x 5 km (approximately half) of the NILS units. The point in the grid defines an area in the aerial photograph that is to be classified. In the initial year (2010) of the project, MOTH surveyed half of the NILS yearly batch, 62 landscape units. The following years (2011–2013), all NILS landscape units (about 120) were surveyed each season. In order to reach a better coverage of certain sparse habitats with a limited range in southern and middle Sweden, such as broadleaved forests and grasslands, the sampling was intensified outside the NILS landscape units during 2012 and 2013 (white units in Fig. 1). This increase doubled the number of landscape units in the Continental biogeographic region and increased the units by about 33% in the Boreal biogeographic region.

During the course of the project approximately 565 units have been inventoried, out of which 120 were additional units. In total, 110814 sampling points have been classified by photo interpreters, and of these 5976 sampling points have been visited in the field.

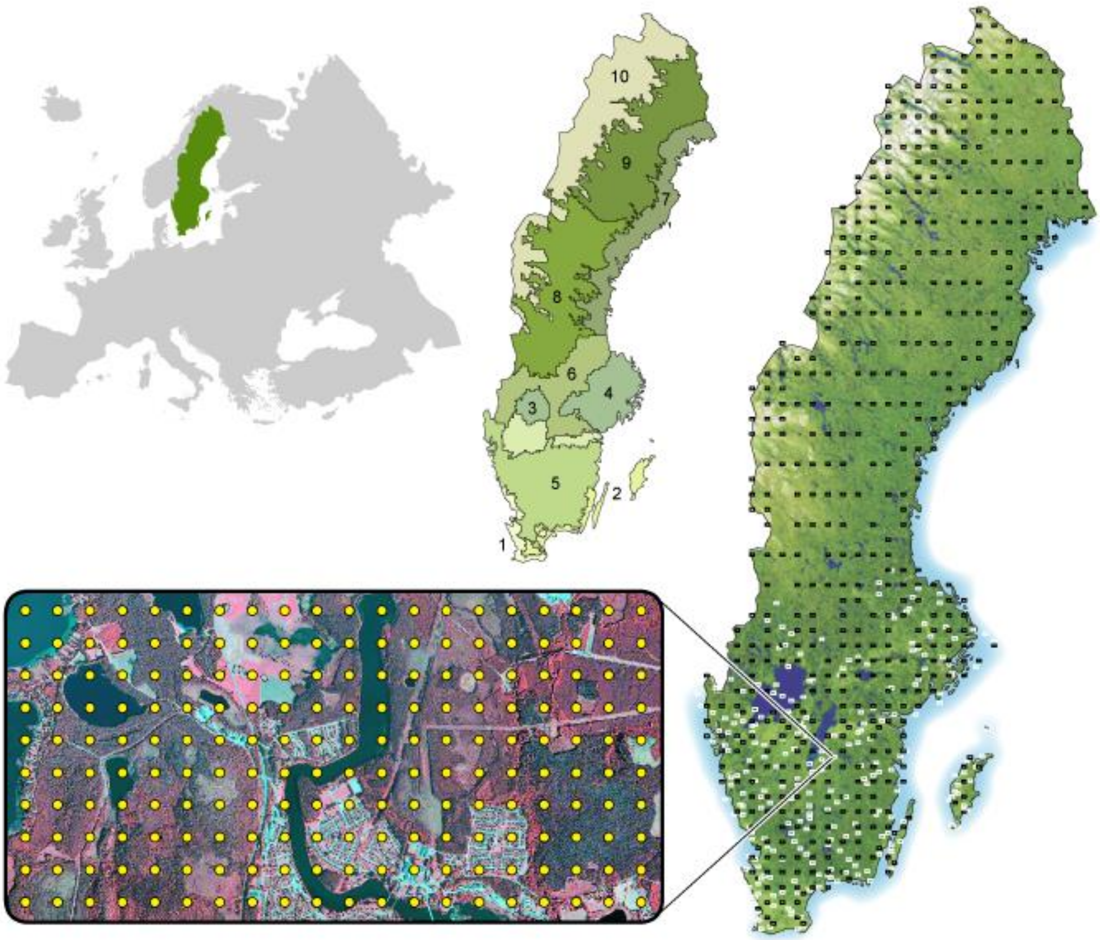


Figure 1*: Upper left part of the figure shows Sweden and the stratification used in the NILS sampling grid of 631 units (Landscape squares). Within these squares, MOTH has inventoried an area of 2.5 x 5 km using an inner point grid. The large map of Sweden to the right shows the units that were sampled by MOTH during the project time (2010-2013). The sample units in black are in the NILS grid and the white in southern Sweden are additional units. The image to the left shows the MOTH point grid in one sample unit (CIR image provided by National Land Survey, 2013). Each of these points is assessed by a photo interpreter.*

1.2.3 Seashore habitat inventory

The point-grid method used in MOTH Terrestrial habitat inventory was designed for sampling habitats that have a random distribution. Based on the knowledge that seashore habitats follow a linear distribution the point-grid method as well as using circular sampling plots to collect field data was deemed inefficient for assessing information on these habitats. MOTH has used a line-intercepting method, consisting of a hexagonal grid, overlain the images of each seashore sampling unit.

The seashore sampling frame was created by using the digital Swedish 5x5 km map sheets (the Property map, Swedish National Land Survey, in the coordinate system SWEREF99). The map sheets were divided by half to create a 2, 5 x 5 km sampling unit (corresponding to the area that is sampled in MOTH terrestrial habitat inventory). Of these, the 3021 sampling units containing Swedish shoreline (defined by conditions set by SMHI and the Swedish Property map) were selected and comprised the population of sampling units for the seashore inventory. A randomly selected 250 unit subset, distributed evenly along the coast, was considered to be an appropriate sampling effort over a five year period, with 50 units being sampled each year (Fig 2).

Within each sampling unit, line segments, organised in hexagons, were created to form basis for the line intercept survey. Hexagons were created with an empty space around the nodes to avoid sampling points being generated too proximate to each other (thus potentially oversampling certain habitats). The grid comprises approximately 1122 hexagon-lines with a total on average 103 355 meters per sampling unit. An unbroken line segment corresponds to 95.5 meters. The intersections between these line segments and the shoreline generates the starting point of the shore transect that form the basis for the assessment area in this survey and from which data is gathered (Fig. 2).

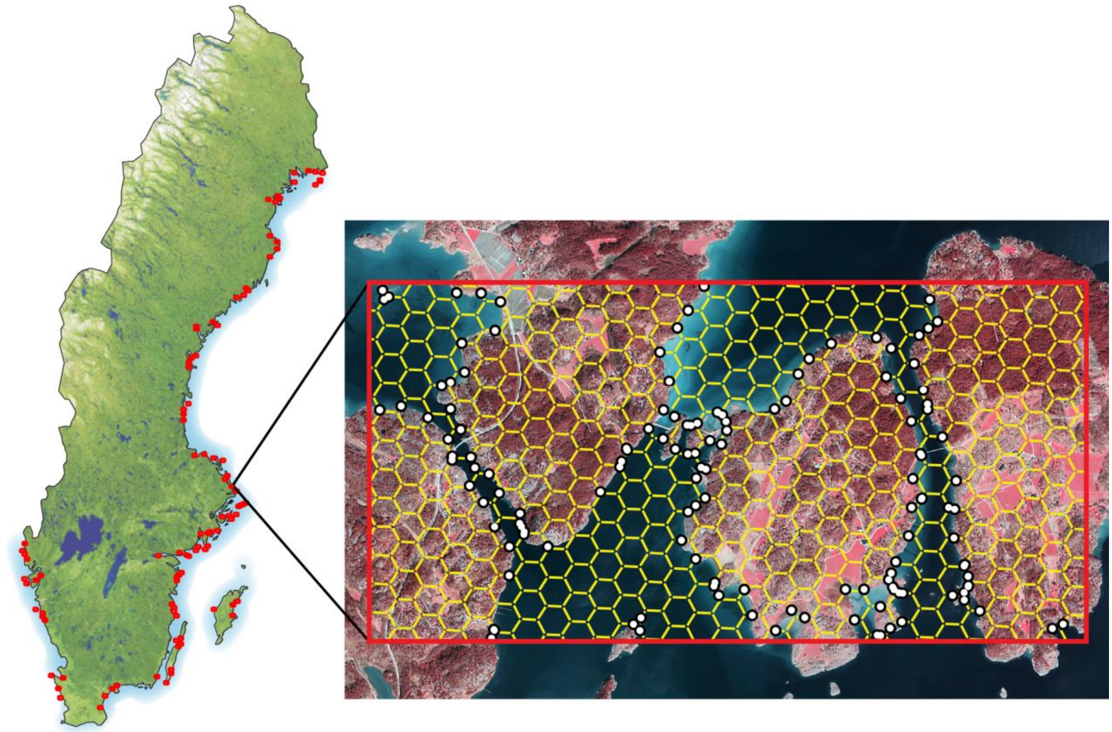


Figure 2*: Map of Sweden shows the seashore sampling units of 2012 and 2013. Enlarged to the right is one sampling unit (2, 5 x5 km) with the hexagonal line segment layer superimposed on a CIR image (CIR image provided by National Land Survey, 2013). The sampling points generated at the intersection between the line segments and the shoreline is indicated in white.*

1.3 Remote sensing method

There are several possibilities available when choosing remote sensing method for the data collection in the two-phase survey designed by MOTH. Colour infrared (CIR) aerial photographs provide one of the best remote sensing sources of information on ecological conditions in the landscape and on the status of vegetation (Ihse, 2007). High spatial resolution satellites can provide data on similar quality (Allard, 2003), but remain an expensive alternative and need to be analyzed together with high resolution elevation data to achieve a three dimensional image (e.g. Groome, et al. 2006; Reese, et al. 2014). The aerial photographs provided by the National Land Survey have in recent years are both readily available and relatively cheap due to the Swedish joint agreement between state departments. Aerial photographs can be interpreted in stereo view, which provide information about vegetation structure and height as well as landscape topography and moisture gradients (e.g. Ihse, 2007; Allard 2007; Morgan et al 2010; Harvey & Hill, 2010). Moreover, aerial photographs combine details and overviews of landscapes (Ihse, 2007), that when manually interpreted can deliver information and data that incorporates vegetation type, status as well as land-use and management. The classification of Annex 1 habitat types involves the assessment of a wide range of land-cover/vegetation types (ranging from forest, to grasslands, mires, seashores and substrate dominated cliffs/screes). Furthermore, in Sweden, the degree of anthropogenic impact on the habitat (i.e. management and status) also needs to be considered when making an Annex 1 classification. Manual interpretation of aerial photographs was the most efficient method available to able to capture all these aspects.

2 Habitat Inventory by Aerial Photo Interpretation

CIR aerial photographs have been used in Sweden for more than 30 years to map and monitor for nature conservation purposes as well as for physical planning of the environment (Ihse, 2007), and continue to be a powerful tool for landscape monitoring purposes, for example in the NILS program at SLU (Allard, 2007).

The “Base inventory of Natura 2000 protected areas” (hereafter referred to as the Base Inventory) was carried out 2004–2008, and aimed towards collecting information about habitats, structures, functions and species within Sweden’s Natura 2000 and other protected areas (Swedish EPA, 2009). The Base Inventory used aerial photo interpretation together with other data sources about the sites (like historical maps, historical aerial photos, current maps, species information from County Boards, etc.) to create new habitat maps with geographical information for every area. The collected data were the basis of management plans for the protected areas with the primary aim of enhancing the conservation status of an area. The data also constituted the basis of the national Article 17 reporting in 2007.

In the Base inventory a classification scheme was developed by Skånes *et al.* 2007, where Annex 1 codes were used to classify habitat polygons meeting the criteria visible during interpretation combined with information from the other sources. The classification schemes used in MOTH terrestrial habitat inventory are based on the system developed for the “Base Inventory”. However, due to differences (for example the use of different supplementary data), between these projects the schemes needed to be modified to meet the objectives in MOTH. These classification schemes are discussed further in section 3.2.

In the seashore inventory, the project could not rely on similar studies or previous classification systems and therefore needed to create a new system that suited the project aims. Photo interpreters do not classify AI-habitats in the seashore inventory, but rather classify substrates that correspond well with Annex 1 habitats, along with a range of other descriptive variables. The need to define the start and end point of the seashore and the position of the shoreline has been an important part of the project and subject of recurring discussions. We have chosen to define the *seashore* or the littoral zone as the part of the shore that is directly influenced by marine water, i.e. either periodically submerged or influenced by waves or sprinkled with water (i.e. the splash zone). How this area is inventoried is described in sections 4.0 to 4.2.

2.1 Equipment and aerial photographs used during interpretation

Inventory is performed through interpretation in colour infrared (CIR) aerial digital photographs in stereo view by experienced photo interpreters. The digital CIR aerial photographs used during the project run-time have been supplied by a range of distributers (Finnmap, Blom, and Scankort) but the majority have been obtained from the Swedish National Land Survey (Lantmäteriet). MOTH has purchased and used the latest images possible for interpretation, meaning predominantly using images 1-2 years old. However in rare cases where data has been missing 5 year old images has been used for interpretation. The flying height when photographing is generally 4800 meters and the spatial resolution in the images is approximately 0.5 meters per pixel (National Land Survey, 2014; Allard, et. al. 2007). In MOTH aerial photographs captured with a digital sensor has mainly been used, and occasionally also scanned analogue aerial photographs. However, all interpretation has been performed in digital images, using a digital photogrammetric workstation (Fig. 3). The stereo model is achieved through overlapping (60%) of images that are viewed on a high resolution screen with a polarising filter using special 3D-glasses. Through zooming using a Stealth mouse different objects and areas of a model can be viewed (Allard, et al. 2007). Software used in the workstation is Summit Evolution (DAT/EM), which handles 3D images and ArcMap (ESRI) was used to create our databases.

Figure 3: *Photo interpreter performing manual interpretation at a digital photogrammetric workstation (Photo: Cronvall, 2012).*

3 Terrestrial Habitat Inventory Methodology

Inventory by manual interpretation of aerial photographs generally involve delineation of polygon boundaries and classification of various variables in the polygon by a photo interpreter (e.g. Base Inventory and NILS). By limiting the number of variables to be classified in MOTH, the inventory by photo interpretation was made more efficient. Inventory time is also reduced by minimizing the amount of digitalization needed, when classifying a point (Fig. 1and 4) instead of digitalizing a polygon. However, the polygon idea, thought of as an assessment area, needs to exist in the mind of the interpreter as classifications are still bound to scale criteria (see 3.1.1).

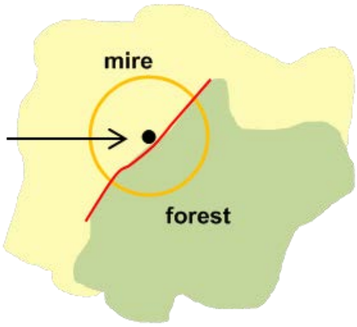


Figure 4: *Schematic illustration of a gridpoint and how it defines the area to be classified by the interpreter. The 10 meter radius circle is the area assessed in the field.*

The selection process in phase two assumes equal information availability for each classified gridpoint in MOTH. Consequently, the aim has been to keep data available for the assessment of each point as equal as possible for the whole country. This means only data sources that are nationally available has been utilised during interpretation. Data sources used in MOTH interpretation were:

- Recent aerial photographs in stereo of the sampling unit,
- The digital Property map (the most detailed map of Sweden),
- The nationwide GSD Orthoimage (both in colour and CIR) provided by the National Land Survey, and
- For spring images (photographed prior to leaf growth) it has been allowed to use the support of old images (>5 years) for the sampling unit from the NILS image library.

Documents used during interpretation has been the Aerial Classification Keys (Skånes *et al*, 2013), the Instruction for Habitat Classification in NILS/MOTH (Gardfjell and Hagner, 2013) and some additional instructions, for example listing of minimum mapping unit requirements for different habitat types.

Once a new project, a sampling unit, is loaded in the workstation the interpreter normally works through the stages described below:

1) Make a quick overview of the area in the sampling unit, both in the property map and aerial photograph to get an idea of the overall landscape context and geographical region of the unit.
2) Observe the overall land types present in the landscape unit to get a rough idea of the parts of the classification scheme that will be used when classifying points.
3) Zoom in to the individual points in the sampling grid to make a qualitative assessment of the area, classify habitat and other variables (according to the stages i-iii, listed in section 3.1). See also overview in figure 5.

3.1 Working process and criteria assessment in classification of a grid point

Regardless of the methodology used (polygon delineation or point classification) the photo interpreter recognizes areas with similar properties, with a range of characteristics, such as tone and colour, shape, size, pattern, texture, shadows, geographical site with abiotic factors and ecological context. The photo characteristics also relate to current and past land use properties on the ground (Ihse, 2007; Morgan et al. 2010; Lillesand & Kiefer, 1999).

The separating properties in aerial photo interpretation largely depend on what classification is intended. As MOTH targets certain Annex 1 habitats the delineating properties in the project relate to descriptions of these habitat types. However, Annex 1 habitats are many times identified based on variables that can only be observed in the field. Therefore the codes used in MOTH needed to be modified to be suitable for inventory by aerial photo interpretation (section 3.2). Moreover, the overall certainty of classification in aerial photo interpretation cannot compare to identification in the field where a range of variables may be measured to confirm a classification. As the classification of a habitat during aerial photo interpretation and classification in the field involve such disparate circumstances, we cannot expect a 1:1 relationship between these. An aerial interpreted classification should thus be viewed as a *code with high probability* to include the *field Annex 1 habitat* with the corresponding code. To differentiate the Annex 1 field definition from the code used in aerial photo interpretation we use the prefix **AI** for the aerial photo interpretation code in this report. However, while potentially confusing to the reader, this text both discusses habitat types as they are defined in the field and how they are recognized in the aerial photo.

Each point in the grid (Fig. 1, Fig. 4) defines a point in the landscape and the interpreter recognizes an area of similar properties around the point (landscape polygon). The properties that separate areas from each other are based on a mixture of vegetation type, landform, - type, and land use. The interpreter then goes about classifying the point according to the following steps:

i. The area of assessment (landscape polygon) needs to meet MMU requirements (section 3.1.1)
ii. Classification of habitat type according to classification scheme (section 3.2)
    a. For AI classifications pointing to Annex 1 habitats the landscape polygon needs to fulfill criteria of naturalness (section 3.1.2)
iii. Land use is registered for each point and special classifications are registered for certain occurrences (section 3.1.3 and Appendix 1).

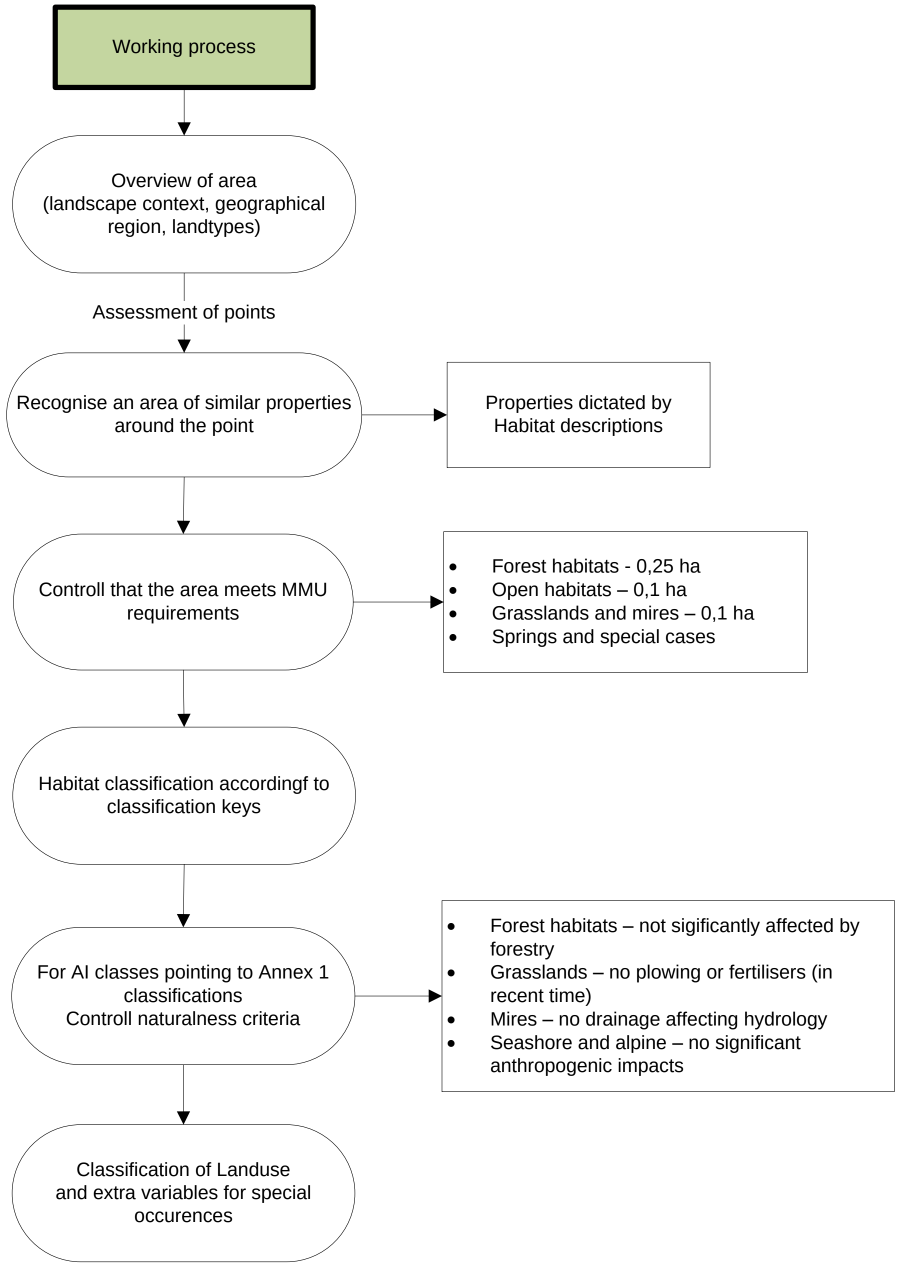


***Figure 5**: Schematic summary of working process in MOTH terrestrial habitat inventory by aerial photo interpretation. The steps in the process are described in more detail in later sections.*

3.1.1 Minimum mapping unit (MMU)

The area of similar properties or landscape polygon needs to fulfill scale requirements before it can be classified. This means it needs to be a minimum area, length and width in order to be classified according to our system. The minimum area requirements for classifying a polygon is generally 0. 1 ha for open habitats, such as grasslands and mires, and 0. 25 for forested habitats (Table 1, Fig. 6). If the sampling point falls in a landscape polygon that does not fulfill the area requirements, the area is incorporated (generalized) in the surrounding or adjacent landscape polygon (Fig. 6 c) and classified accordingly. There are also some rules relating to width of linear landscape elements.

- Naturally occurring landscape elements (i.e. forest border along watercourse or forest boundary around mire) can be given a forest classification down to 10 meters width (Fig. 6 d).
- Forest polygon with a shape resulting from anthropogenic impact, e.g. forest borders remaining after timber harvesting; need to have a width of at least 20 meters to be given an AI Annex 1 forest classification.

A point is regarded as infinitely small it can therefore by definition never fall on the border between two habitat polygons. Due to this fact interpreters have not worked with precedence rules for this type of problem. However, due to limitations of working with a digital photogrammetric workstation, an interpreter can sometimes but not always solve uncertain cases by zooming closer to the ground. In cases where the point *appears* to fall on the border between two habitat types it is classified as the type that dominates the 10 m radius circle (Fig. 6 b).

Table 1*: Minimum mapping unit (MMU) for different habitat types applicable in both photo interpretation and field based stages of habitat classification.*

Habitat type	**Minimum Mapping Unit (MMU)**
Forest habitat types	0.25 ha generally
Open habitat types (e.g. coastal and alpine habitats)	0.1 ha generally
Mire and Grassland habitat types	0.1 ha generally
Springs	Regarded as point objects without actual MMU
Special cases	MMU of some substrate dominated and coastal habitats are defined differently from the above (detailed information can be found in field manual by Gardfjell and Hagner, 2014)

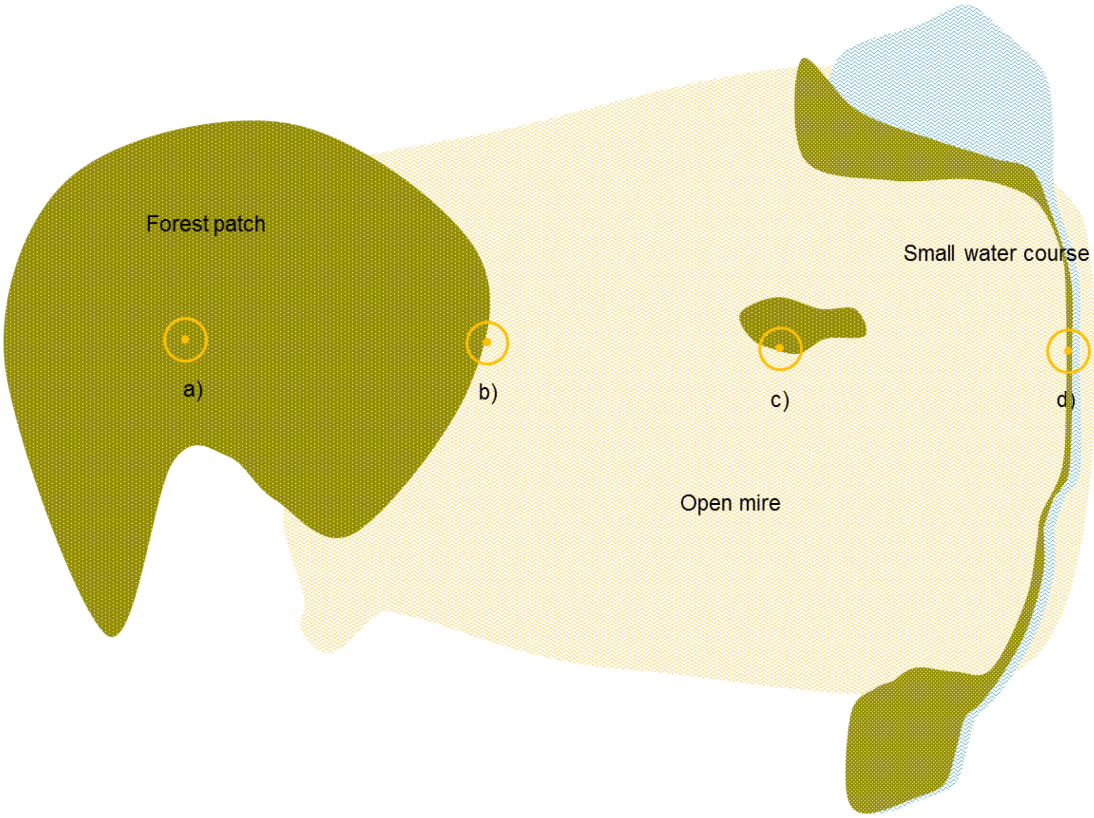


Figure 6: *Schematic illustration of example grid points and descriptions of how these would be classified in relation to MMU requirements and rules for generalization (incorporation in surrounding polygons). The first example is straightforward as point* ***a)*** *falls in forest patch that fulfills area and width requirements for forest classification (>0. 25 ha and >20 m wide forest patch). Point* ***b)*** *falls at the edge between forest and mire and would be classified as mire because this habitat type dominates the 10 m circle. Point* ***c)*** *falls in a small (<0. 1 ha) forest patch that does not meet area requirements and is therefore generalized to the surrounding mire polygon. Point* ***d)*** *falls into a narrow forest patch bordering a small watercourse and would also be classified as mire because the forest does not meet width requirements (< 10m wide).*

3.1.2 Criteria of naturalness – degree of anthropogenic impact

The interpreter needs to continually assess the degree of anthropogenic impact for each point as AI classifications pointing to Annex 1 habitats require a certain degree of naturalness. These criteria are specified for each group of habitats generally and for certain habitat types (e.g. alpine screes) specific requirements are set. The criteria of naturalness are based on characteristics measured or observed in the field, but some can also be seen in an aerial photo. The criteria as they are stated for field classification are listed below and how these are translated to features that can be identified in aerial photos is described for each group of habitats below. The criteria are assessed within an area around the point matching the size set in the minimum mapping unit requirements.

Signs of mechanized forestry are often visible in aerial photographs, and is a strong indicator of anthropogenic impact that has a negative effect on the naturalness of the area interpreted, but when less invasive methods are used it will more difficult to see and determine the impact. Naturalness criteria are many times a source of uncertainty for the interpreter, as we cannot make the field measurements necessary to make the classification. This is one of the reasons collection codes are used (see section 3.2), which are codes that include 2 or more AI classes reflecting the uncertainty of the interpreter. An example is AI 9810 (9010/9900), which is a combination of AI *9010 Taiga* and AI *9900 Non-Annex 1 forest* used in cases the interpreter is uncertain of forest management status. Interpreters are also instructed to have an 'including approach' during classification, meaning that AI classes that points to Annex 1 habitats or collection codes are used unless completely certain that the habitat is significantly affected by anthropogenic activities. Thus, the code AI *9900 Non-Annex 1 forest* is only used when the interpreter is certain a forest is significantly affected by forestry activities.

Forest **(from field manual Gardfjell & Hagner, 2013)**

For *forest habitats*, all of the following criteria have to be fulfilled:

1. The stand originates from natural regeneration.
2. Large-scale cutting or thinning has not taken place during the last 25 years.
3. In moist or wet stands, no ditches, roads etc. within 25 metres from the plot center affect the hydrology of the plot in an obvious way.

In addition, for *forest habitats*, at least one of the following criteria has to be fulfilled:

4. Stand age exceeds lowest recommended final stand age with at least 40 years.
5. The amount of dead wood exceeds 10 m^3/ha, *or*, the stand is multi-layered, *and*, stand age exceeds lowest recommended final stand age with at least 20 years.
6. The stand is not of equal age, and there are at least eight old standards per hectare of oak, beech, elm, lime or maple, exceeding lowest recommended final stand age with at least 40 years.
7. The stand is not of equal age, and there are at least 80 standards per hectare of spruce or pine, exceeding lowest recommended final stand age with at least 40 years.
8. The area is affected by important natural disturbances such as fire, storm, or flooding, or by management actions aimed at imitating such disturbances (Gardfjell and Hagner, 2013).

The criteria listed above concerns *age*, *natural regeneration, absence of forestry actions*, and *structural characteristics* such as dead wood. Structural aspects are often difficult to see in aerial images, with the exception of standing dead wood. However, while an exact measurement of remaining variables cannot be performed in an aerial photograph, the interpreter can get an idea of remaining criteria. Through assessment of variables such as height, structure, pattern and colour tone of the forest stand, the relative age can be estimated. For example, an older, naturally regenerated forest has a relatively uneven structure, often darker in colour and has higher trees relative to a planted forest with a younger age (Fig. 7). Indications of forestry activities can be quite evident in an aerial photograph. The line pattern of planted forest is easily distinguished from above even when the forest has become older. Likewise are tracks and roads used for logging and thinning often easy to identify in aerial photographs.

***Figure** 7: CIR image illustrating different management of forest stands (CIR image provided by National Land Survey, 2013). The area in ring B is dominated by young planted coniferous forest, easily distinguished by the bright red colour and line pattern, whereas the forest in ring A is dominated by mature, naturally regenerated forest, seen by the uneven growth pattern and height of the trees.*

***Wetland* (from field manual Gardfjell & Hagner, 2013)**

For *wetlands*, both of the following criteria have to be fulfilled:

9. No ditches, roads etc. within 25 metres from the plot centre affect the hydrology of the plot significantly.
10. The area is not the subject of any substantial chemical influence such as the distribution of limestone to counteract acidification, or the leaking of fertiliser from arable land (Gardfjell and Hagner, 2013).

Ditches are structures that are easy to identify in aerial photos. In fact, the areal extent of ditching can probably be better studied in aerial photographs than from a field perspective (Fig. 8). However, determining the actual impact of ditching in wetlands can be problematic both in the field and when studying aerial photographs. In this inventory the following rules have been applied during interpretation:

- Mire grid-points with ditches within 25 meters that have caused significant hydrological impact are classified AI 7900 Non Annex 1 mire.
- Mire grid-points with a ditch within 25 meters, where the interpreter do not see that the ditch have had any significant hydrological impact and can see that the vegetation is unchanged from the rest of the mire, the point can be classified with AI-mire codes. However, these receive a note for ditch (719).
- Mire grid-points with a ditch within 25 meters, where the interpreter is ***unsure*** whether the dich has caused significant hydrological impact on the area, the point is classified AI 7900 Non Annex 1 mire.

As the general rule is to exclude mire points within 25 meters from ditches by classifying them AI 7900 Non Annex 1 mire, the overall approach towards mire points is an including one because the interpreter is instructed to have a closer look at the vegetation effect around the ditching.

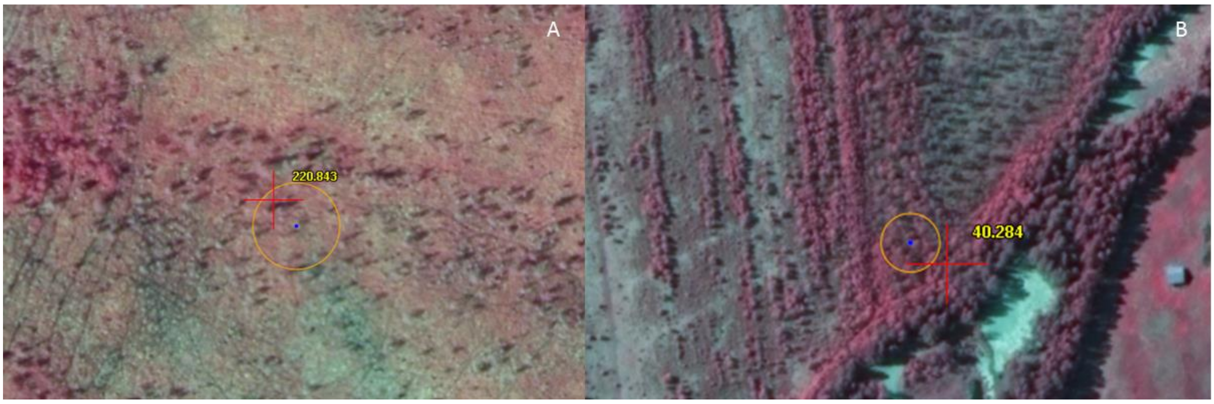


Figure 8*: CIR image illustrating ditching and vehicle tracks on wetlands (CIR image provided by National Land Survey, 2013). Image A shows a wetland with line pattern that is probably a result of vehicle tracks. The hydrology on and around the sampling point does not seem to be significantly affected. Image B on the other hand shows a wetland where ditches have altered the hydrology around the sampling point and the vegetation has changed as a result, seen as the pink growth of deciduous trees and shrubs along ditches.*

Grasslands (from field manual Gardfjell & Hagner, 2013)

For *grasslands*, both of the following criteria have to be fulfilled:

11. The area is not affected by fertilization or cultivation through ploughing, harrowing etc.
12. If the area is in the process of being overgrown, values connected to trees or field layer are still present (Gardfjell and Hagner, 2013).

To distinguish between arable land and semi-natural grasslands in aerial photographs can be obvious but sometimes also difficult depending on time since and extent of cultivation. Arable land generally has an even structure and surface as well as ploughing contours and absence of boulders. Semi-natural grasslands are kept open by traditional management regimes such as grazing or hay meadow management, which results in a more uneven surface, presence of boulders and shrubs and sometimes trees (see Fig 11a). To determine how land-use history affects the grassland today (in terms of species assemblage) is difficult when structures relating to land-use are less obvious. In these cases the photo interpreter has a number of collection codes to work with, indicating uncertainty of the grassland management status.

Coastal habitats (from field manual Gardfjell & Hagner, 2013)

For *shore habitats*, all of the following criteria have to be fulfilled:

13. The shore has not been exploited or built on.
14. The shore line has not been significantly affected by digging, dredging or the construction of jetties.
15. Forests along the shore line have not been affected by large-scale cutting or thinning.
16. Shores along lakes and rivers may not be significantly affected by water-level regulation.

For *dunes* and *sands*, all of the following criteria have to be fulfilled:

17. The hydrology is not significantly affected by ditches.
18. The area has not been exploited or built on.
19. If the dune is forested, this should be the result of natural regeneration of tree species naturally occurring in Sweden (Gardfjell and Hagner, 2013).

Coastal habitats are targeted in the Seashore Inventory (described in chapter 4 in this report), which handle the question of exploitation in a different manner (see section 4.2.7). However, while the grid-point design is not optimal for surveying these habitats they are not completely absent in this inventory. Most of the criteria listed above are possible to identify in aerial photographs, although to determine whether effects of anthropogenic exploitation has been significant to the specific habitat is difficult. In case of uncertainty, collective codes have been utilised, but in most cases an including approach has been adopted, meaning shore habitats have been given an AI class that points to Annex 1 habitats unless certain that the habitat is significantly affected. Due to the fact that coastal environments are handled in the Seashore Inventory these have not been the primary focus in the Terrestrial Inventory.

***Alpine habitats* (from field manual Gardfjell & Hagner, 2013)**

In the *alpine mountains*, criteria 9–10 are applicable for wetlands and 1–3 for forests. In addition, all of the following criteria have to be fulfilled:

20. The area is not significantly affected by erosion or ditches due to terrain vehicles, tourism etc.
21. The area has not been exploited or built on.
22. In subalpine birch forests, stand age should exceed 60 years and the forest should not be affected by large-scale cutting or thinning (Gardfjell and Hagner, 2013).

Alpine habitats are confined to areas that have experienced less anthropogenic impact than habitat groups in remaining Sweden. Activities relating to reindeer herding do not normally disqualify Annex 1 classifications. In most cases, diches, erosion and buildings can be identified in aerial photos. But as with earlier cases, the extent of the effect from these disturbances is more difficult to determine. Nonetheless, naturalness criteria are rarely a problem in alpine areas. Forest naturalness criteria regarding forest activities are the same as in other forest, however the age criteria for Nordic subalpine birch forest (9040) is only 60 years.

3.1.3 Land use and special occurrences

When conducting a national inventory such as MOTH and sampling a total of 110 814 points during the run time of the aerial photo interpretation habitat inventory, it is tempting to make additions to the variable list. Land use has been an additional classification since the start of the project. This class is a combination of land cover and land use (Table 2) and is based on the definitions used in the NILS field inventory (Sjödin, M. red., 2014). This variable is recorded as it gives valuable of information about land cover and use at each sampling point, which can be used in later analyses. However, the information has not been used in the selection process in this two-phase design.

Other additional occurrences have been noted during interpretation, such as snow beds in alpine areas, and small islands (<0.1 ha) in lakes and watercourses, that otherwise would have been generalized to the water code. Aapamire has been indicated by a note as well as reason for classifying certain non-annex 1 AI codes. These additional notes are listed in Appendix 1.

Table 2*: Land use/land cover classifications registered for each sampling point (modified from Sjödin, M., 2014).*

1. Arable land	**10 Fallow/no apparent current use**
	11 Recent earth work/plowing/harrow/seeded
	12 Annual crops
	13 Hay field/ley (traces of plowing within the last 5 years)
	14 Grazed ley
	15 Energy forest
	16 Fruit/berry plantation
	19 Unspecified arable land (type not possible to interpret in photograph)
2. Man-made/paved or developed area	20 No apparent current use
	21 Allotment garden
	22 Recreational area
	23 Built up area (including houses, urban- and farm buildings)
	26 Industrial area
	27 Transport (roads, railway parking lots)
	28 Current exploitation/road/building site
	29 Unspecified man-made (type not possible to interpret in photograph)
3. Forest	30 Potential forestry (no signs of current forestry management)
	31 Forestry management
	32 Forestry, retention area (conse rvation)
	33 Clear-cut area
	34 Seed orchard
	35 Power line corridor
	36 Grazed forest (+managed forest)
	37 Recreation (+managed forest)
	38 Recently tree planted field
	39 Unspecified forest (management type not possible to interpret in photograph)
4. Other/Natural land	40 No apparent current use
	41 Grazing animals on semi natural grassland (not fertilized or plowed)
	42a Grazing animals on formerly cultivated grassland (fertilized and/or plowed)
	42b Hay field on formerly cultivated land (plowing > 5 years)
	43 Hay field/mown meadow traditional management (not fertilized or plowed)
	44 Recreation (natural areas)
	45 Residental lot (not dug or excavated)
	46 Excavation (sand or gravel mining, peat cutting)
	49 Unspecified other/ natural land (type not possible to interpret in photograph)
5. Water	

3.2 AI Classification schemes – Terrestrial habitat inventory

Aerial photo interpretation of AI habitats in MOTH has been performed with the AI classification keys as the major basis for classification. This system of codes is based on the classification scheme developed by Skånes *et .al* 2007 during the Base Inventory, where Annex 1 codes were used to classify habitat polygons meeting the criteria visible during interpretation combined with information from the other sources. The formal definitions of an Annex 1 habitat are based on the Swedish Environmental Protection Agency's (Swedish EPA) interpretation of EU's definition of habitats listed in the directive (Swedish EPA, 2012; European Commission, 2007). However, these definitions were modified to suit an inventory by aerial photo interpretation and the system has been modified further in MOTH to account for the differences between these projects.

It is worth mentioning again that MOTH classifies habitats both during phase one, aerial photo interpretation, and during phase two, field sampling. It has therefore been especially important to differentiate between these disparate classification circumstances and highlight that one cannot expect a 1:1 relationship between these. The aerial interpreted classification should be viewed as a *code with high probability* to include the *field Annex 1 habitat* with the corresponding code and is distinguished from the Annex 1 field definition by using the prefix **AI**.

In many cases it is impossible to make an AI classification with 100% certainty in aerial photo interpretation, and the reason for using many code-varieties in the classification system. The aerial photo interpreter needs to use collection codes, which are codes that include 2 or more AI classes reflecting the uncertainty of the interpreter (Table 3). Thus, the certainty of classification is not recorded, but is communicated indirectly by what type of code is used by the interpreter. A wide collection code, including many AI classes indicates that the interpreter is uncertain of the AI habitat class, whereas a narrow habitat specific code indicates confidence in the classification. It was in the Base Inventory stated that an interpreter should feel approximately 80% certainty when making a classification; otherwise the interpreter should move back the hierarchy and choose a wider collection code (Skånes, 2007).

Table 3*: AI class-types used during MOTH terrestrial habitat inventory. For each AI-class type an example of AI-code and the included AI habita classes is given.*

AI Class type	Description of AI class type	Example AI class (included AI habitat classes)
α	Single AI habitat class	**AI 9040** Nordic subalpine birch forest
β	Collective code for AI classes from similar habitat groups	**AI 6815** Collective code for alpine grasslands (calcarerous 6170 and siliceous 6150)
γ	Collective code for AI classes from different habitat groups	**AI 4850** Collective code for sub-alpine salix scrub, tall herb community, wet grassland, heath and mire (4060/6815/7000/4080/6430/)
δ	Collective code including both AI classes pointing to annex 1 habitats and non annex 1 habitats	**AI 6845** Collective code for natural, semi-natural grasslands and cultivated grassland (4030/5130/6120/6230/6270/6210 /6510/6520/4010/6430/6450/6915/2320/2330/6510/ 6520 /6910)
ε	Single AI non annex 1 class	**AI 6913** Wooded cultivated pastures
ζ	Group of AI non annex 1 habitats	**AI 9900** Non Annex 1 forest
η	Basecode in series	**AI 1000** Marine waters

The classification system is for this reason complex, containing a hierarchy of class-types ranging from being *habitat specific* (AI α-codes), to comprising a *group of similar habitats* (AI β -codes), to encompassing *broad group of different habitat types* (AI γ -codes). Naturalness criteria are many times a source of uncertainty for the interpreter, as we cannot measure the variables necessary to make the classification. For these cases AI δ-codes (including AI non-annex 1 habitat codes) are used. An example is AI 9810 (9010/9900), which is a combination of AI *9010 Taiga* and AI *9900 Non-Annex 1 forest* used in cases the interpreter is uncertain of the forest management status. A certain AI class can thus be found in many different classes and class types (see Table 3, Fig. 9).

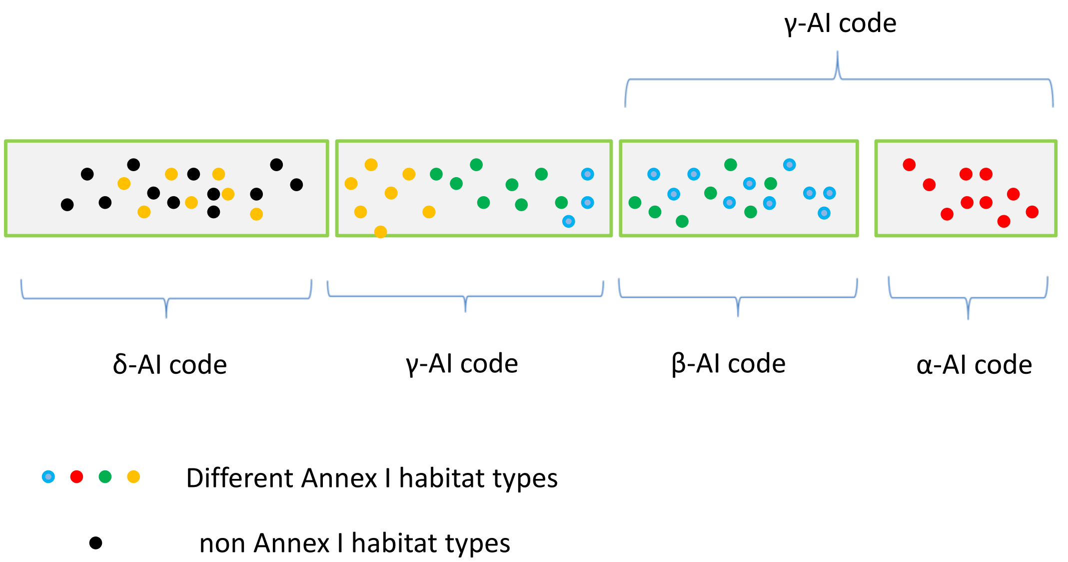


Figure 9*: Schematic presentation of the different AI class types according to how specific they are in relating to Annex I-habitat types. For explanations of code types see Table 3.*

In the Base Inventory interpreters made use of supplementary data such as historical images, species information, and geological maps together with the aerial photographs to make the classification. For areas with less information or lower image quality collective codes were used (Skånes *et .al* 2007). One modification that was necessary in MOTH was simplification, as the less information was available to the interpreter, MOTH needed to classify fewer AI habitat classes. For instance, AI classes that could only be separated with the help of species information are combined. For example *6150 Alpine siliceous grasslands* and *6170 Alpine calcareous grassland* that are in the field separated from each other based on species composition, were merged to one class, in this case called *6815 Collective code for alpine grassland*. The Base Inventory had the choice of using the Annex 1 codes or the collection code depending on information available in each case, whereas only the collection code is used in MOTH aerial photo interpretation phase as no such additional data is used in this project (Fig. 10).

Figure 10*: Illustrates code availability in different inventory situations. In the field, grasslands are separated from each other by species composition and classified with appropriate codes. In the Base inventory interpreters had a choice of using the α-codes or collection code, depending on the available information in each case, whereas MOTH aerial photo interpretation inventory uses only the collection code for this particular case as the information to separate the two is not available to the interpreter.*

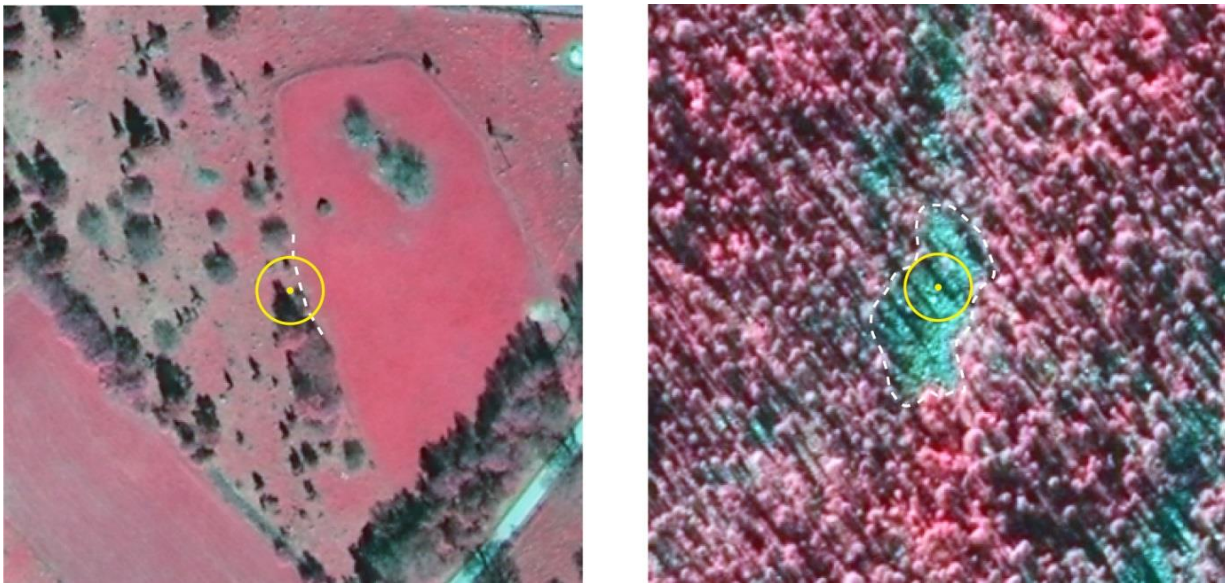
MOTH has also broadened AI classes in two ways. The first can be exemplified by the class AI *6430 Tall herb communities*. For this habitat the interpreter has no way of distinguishing trivial species of tall herbs from the species composition in the Annex 1 class. This AI class is therefore broadened to include all types of tall herb communities in order to reduce the risk not including true Annex 1 *6430 Tall herb communities*. Secondly, AI classes were broadened by instructing interpreters to have an 'including approach' during classification. This means that AI classes, α-codes or collection codes, that points to Annex 1 habitats are to be used unless relatively certain that the habitat is significantly affected by anthropogenic activities. Thus, the code AI *9900 Non-Annex 1 forest* is only used when the interpreter can see clear indications of forestry activities in a forest.

AI habitat classification

While the emphasis in MOTH has not been measuring and registering variables, a number of variables and criteria need to be considered when making each classification. For example, the classification of AI *9040 Nordic subalpine birch forest* involves:

- Assessment of crown cover, which needs to be more than 10% to be classified as forest.
- Tree species composition that for AI *9040 Nordic subalpine birch forest* is dominated by *Betula pubescens var. tortuosa,* which the interpreter cannot directly identify but the region, situation in the landscape and growth pattern of AI *9040 Nordic subalpine birch forest* is often distinctly different from other birch forest.
- Forest naturalness involve criteria such as age, natural regeneration, presence of dead wood, absence of large scale forestry actions, many of which are not possible to measure in aerial photographs. However, naturally generated forest has a relatively uneven structure compared to the planted forest. Forest age cannot be measured in an aerial photo, but the interpreter can get an idea of relative forest age in an area by looking for signs of forestry activities and relative forest height (see section 3.1.2 for information about naturalness criteria).

Two example points are shown in figure 11 below. The first example 11a shows a grazed pasture where the interpreter begins to determine the delineation of the landscape polygon, to go on to assess crown cover and management type. The point in 11a was classified AI *9070 Wooded pasture*, due to signs like boulders, unevenness of the ground, pathways made by cattle, presence of shrubs which all indicate that this pasture is grazed by cattle. Tree-layer (> 10%) continuity makes the classification wooded instead of an open pasture. The second image 11b exemplifies the generalization that is made when MMU requirements are not met. This point would be classified as AI *9040 Nordic subalpine birch forest* as the bare substrate patch (<0.1 ha) is generalized to the surrounding forest polygon.



a) ***b)***

Figure 11*: Two illustrations on CIR aerial photos (CIR image provided by National Land Survey, 2013), each showing a point in the grid. In image* ***a)*** *the point falls in grazed wooded semi-natural grassland with solitary trees and a few shrubs. Note the more even surface of the arable land to the right of the decked line. The line is drawn by the interpreter to illustrate polygon boundary to the field staff and which polygon is actually classified by the interpreter. In* ***b)*** *the point falls onto a patch of bare substrate, surrounded by mountain birch forest. The decked line in this case would not be drawn, but here illustrates that the open polygon when assessed for MMU in this case found to small (<0.1 ha) and therefore generalized to the surrounding polygon.*

Furthermore, other variables such as percentage shrub cover, soil moisture, presence of peat layer, and management aspects such as presence of grazing are important elements that determine which classification key to use as well as separate AI classes from each other. Figure 12 below describes how the interpreter would initiate the classification the sampling point in figure 11a above. In this case the main key leads to the grassland key by the indication of grazing seen in the aerial photos (Fig. 11 and 12).

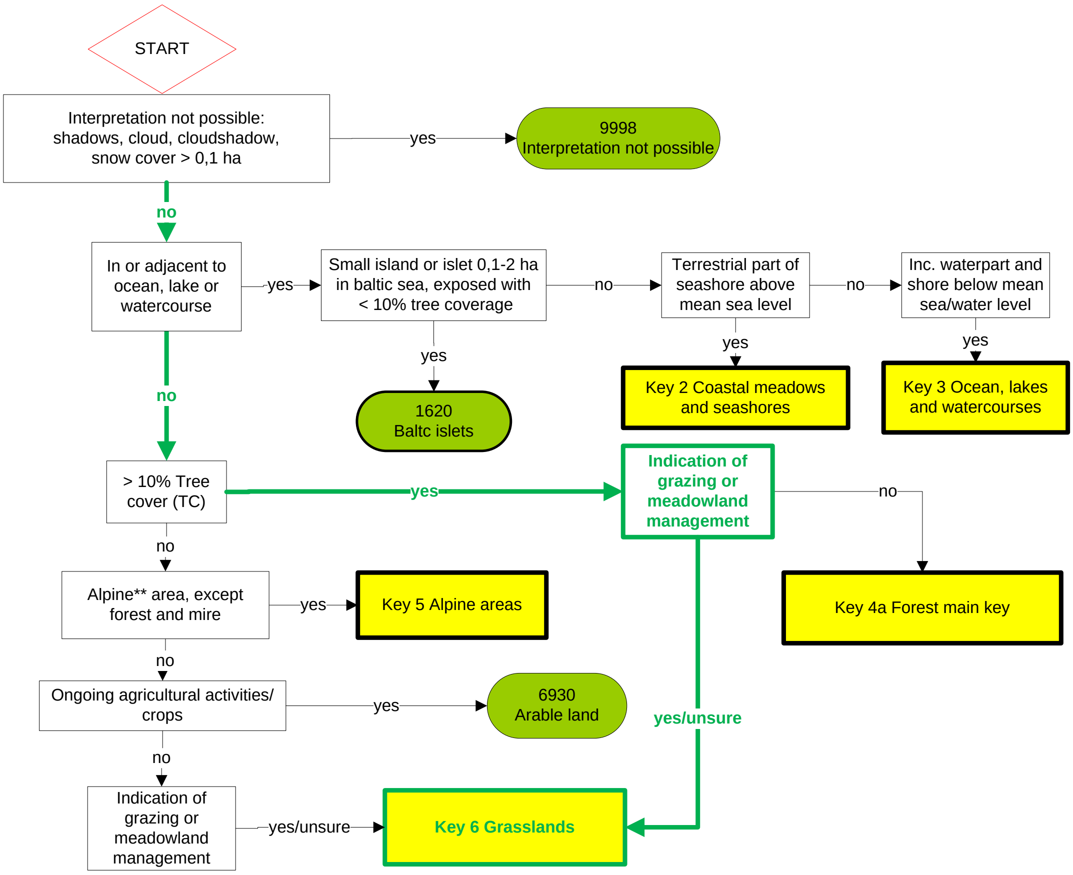


Figure 12*: Section of AI classification scheme, Key 1 Main Key, indicating in green how the example in fig 11 a) would be classified. The interpreter would then go further to key 6 Grasslands for finer classification.*

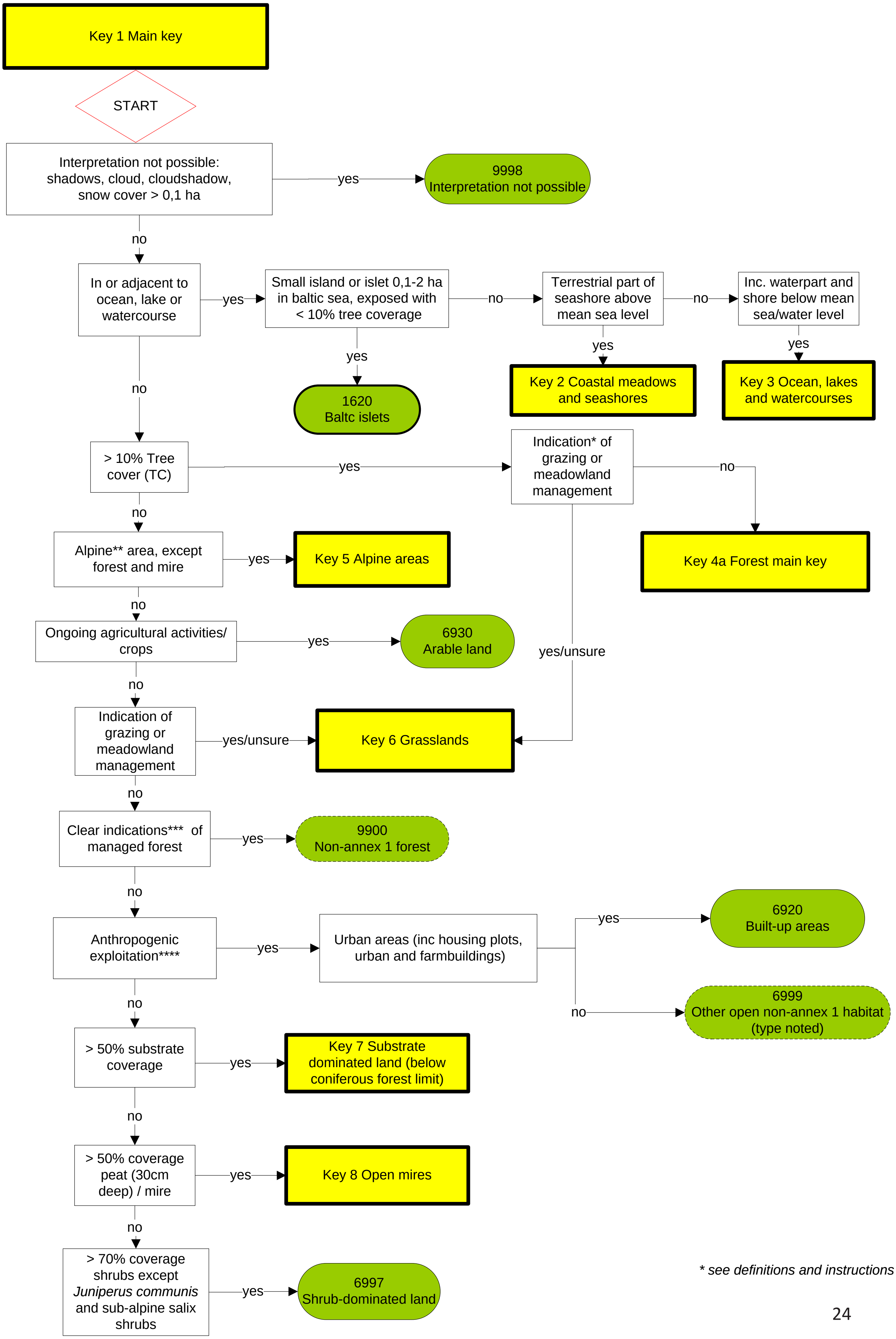
The classification keys in MOTH have been developed in collaboration with Helle Skånes (Department of physical geography, Stockholm University) and Anna Andersson (National Land Survey, Luleå). The classification keys are one way of describing in what cases a certain AI class is suitable to use. The keys thereby define the limits around each class as they direct the interpreter with simple questions. These limits or class definitions can also be communicated in text. It is not possible to make a detailed description of all the AI classes in this text, but a summary text as well as an example AI class from each key is included in section 3.2.1 – 3.2.9. A comprehensive list of all AI classes available during the project time can be found in Appendix 2.

3.2.1 Key 1 Main key

The main key gives the interpreter an overview of the AI classification keys existing in the manual and in which cases (for which habitat groups) these should be used. Certain classes (containing primarily non-annex 1 habitats) fall out in the main key. Some of these class codes reoccur in other keys, while others such as AI 6920 Built-up areas occur only in the main key.

Example AI-class - 6920 Built-up areas

AI 6920 defines a Non-Annex 1 type that has non-natural conditions as a result of anthropogenic activities. Comprises all forms built-up areas including urban as well as rural and farm buildings. The code also includes surrounding lawns, and is delineated against bordering habitat types by the plot boundary. MMU requirements are 0.1 ha for this class. This class is not part of any collective codes.



** see definitions and instructions*

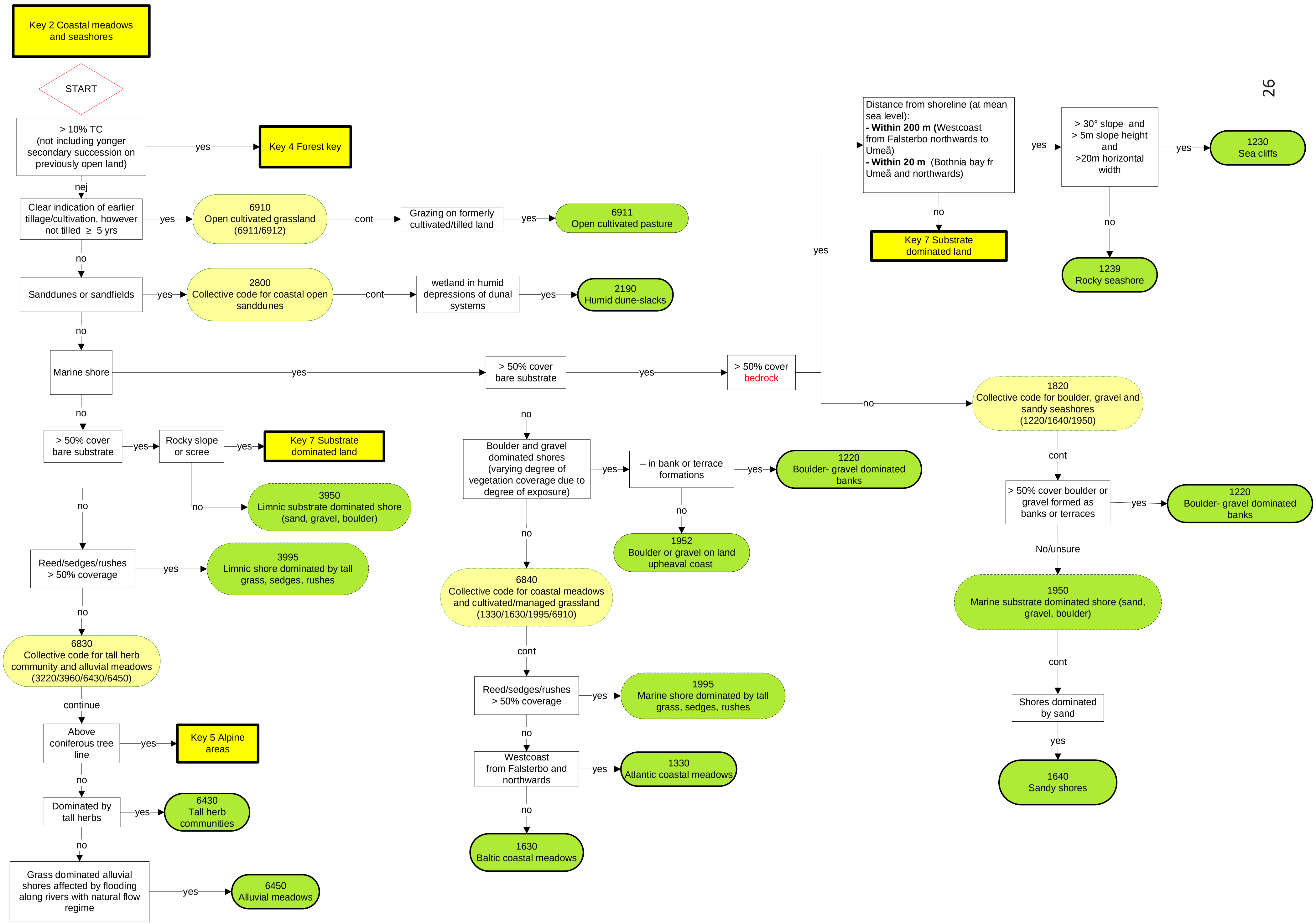
3.2.2 Key 2 Alluvial meadows and seashore habitats

This key comprises AI classes in some way associated with water. These include both the limnic AI *6430 Tall herb communities* and AI *6450 Alluvial meadows*, usually occurring along rivers, and the marine shore habitats AI *1630 Baltic coastal meadows* and AI *1230 Sea cliffs*. Dune habitats, despite not being strictly coastal, also fall out in this key. Also defined here are a number of non-annex 1 habitat types occurring on both limnic and marine shores, such as those dominated by reeds sedges and rushes and substrate shores that do not fulfil the criteria for Annex 1 classification.

Example AI class– 6450 Alluvial meadows

Grass dominated area along large rivers with near natural water regime. The growth of bushes and trees is reduced in this zone by flooding and ice movements. This riparian zone is used or has historically been used for hay harvesting. Alluvial meadows are thus kept open by both anthropogenic and natural disturbance. The AI class is delineated towards limnic habitat types where the grass no longer dominates the vegetation. Delineation against lowland grasslands is more diffuse, but can usually be separated from those due to their more even structure.

Identification in CIR aerial photo is based primarily on situation in the landscape and the irregular vegetation structure often visible in the image. This can however be difficult to separate from tall herb communities that occur in similar situations but the grass dominated meadows are often more zonated compared to the herb commuity. The tall herbs also have a more rich red in CIR photos than do the grass dominated meadows. In situations where the interpreter is unsure it is possible to use the AI-code *6830 Collective code for tall herb community and alluvial meadows (6450/6430).* Other potential misidentification could be *Phragmites* dominated shores; however, these often have a much more homogenous structure (Skånes, 2007).

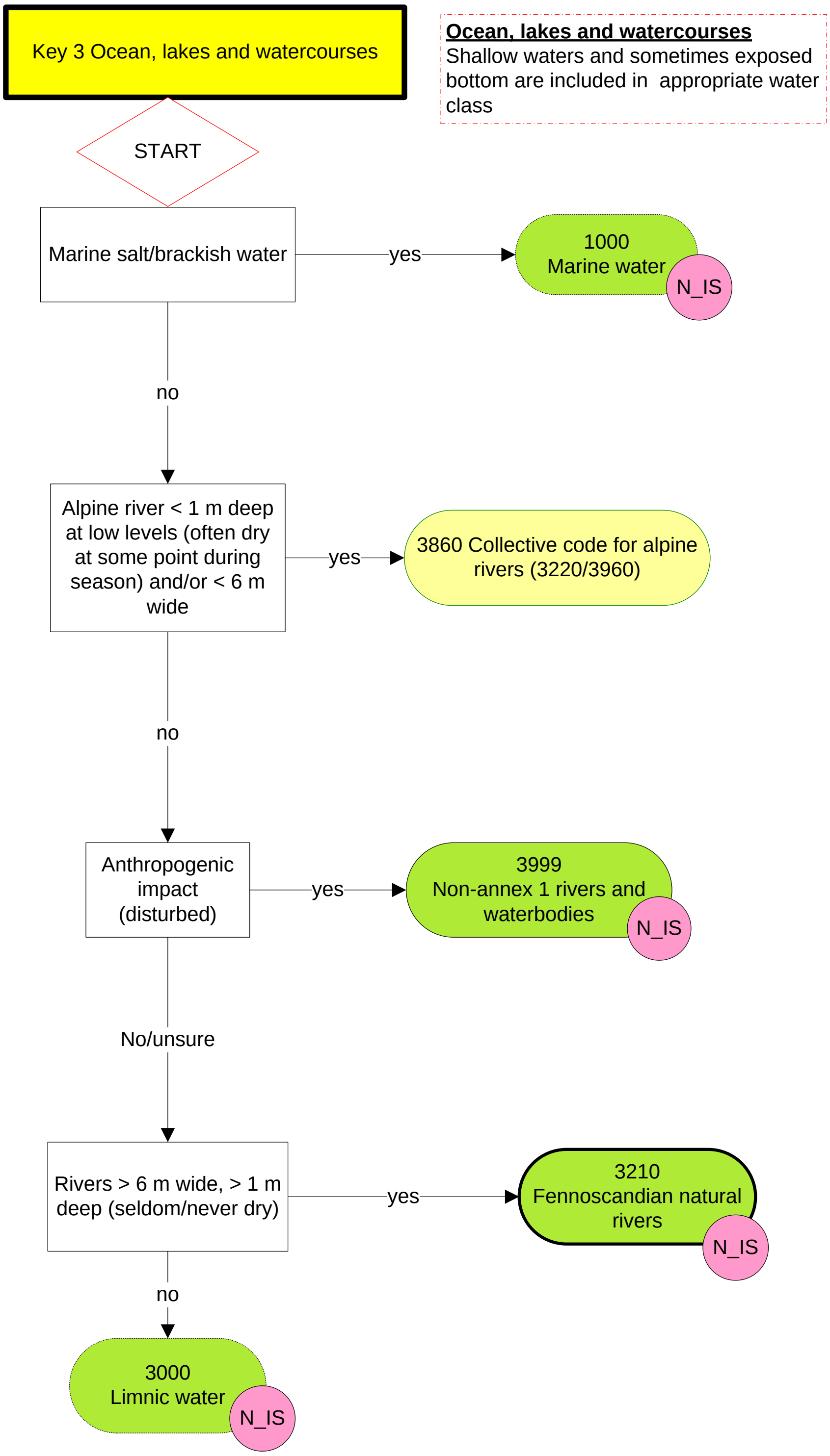

Key 2 Coastal meadows and seashores
START
> 10% TC (not including yonger secondary succession on previously open land)
yes
Key 4 Forest key
nej
Clear indication of earlier tillage/cultivation, however not tilled ≥ 5 yrs
yes
6910 Open cultivated grassland (6911/6912)
cont
Grazing on formerly cultivated/tilled land
yes
6911 Open cultivated pasture
no
Sanddunes or sandfields
yes
2800 Collective code for coastal open sanddunes
cont
wetland in humid depressions of dunal systems
yes
2190 Humid dune-slacks
no
Marine shore
yes
> 50% cover bare substrate
yes
> 50% cover bedrock
yes
Distance from shoreline (at mean sea level):
- Within 200 m (Westcoast from Falsterbo northwards to Umeå)
- Within 20 m (Bothnia bay fr Umeå and northwards)
yes
> 30° slope and > 5m slope height and >20m horizontal width
yes
1230 Sea cliffs
no
1239 Rocky seashore
no
Key 7 Substrate dominated land
no
1820 Collective code for boulder, gravel and sandy seashores (1220/1640/1950)
cont
> 50% cover boulder or gravel formed as banks or terraces
yes
1220 Boulder- gravel dominated banks
No/unsure
1950 Marine substrate dominated shore (sand, gravel, boulder)
cont
Shores dominated by sand
yes
1640 Sandy shores
no
Boulder and gravel dominated shores (varying degree of vegetation coverage due to degree of exposure)
yes
– in bank or terrace formations
yes
1220 Boulder- gravel dominated banks
no
1952 Boulder or gravel on land upheaval coast
no
6840 Collective code for coastal meadows and cultivated/managed grassland (1330/1630/1995/6910)
cont
Reed/sedges/rushes > 50% coverage
yes
1995 Marine shore dominated by tall grass, sedges, rushes
no
Westcoast from Falsterbo and northwards
yes
1330 Atlantic coastal meadows
no
1630 Baltic coastal meadows
no
> 50% cover bare substrate
yes
Rocky slope or scree
yes
Key 7 Substrate dominated land
no
3950 Limnic substrate dominated shore (sand, gravel, boulder)
no
Reed/sedges/rushes > 50% coverage
yes
3995 Limnic shore dominated by tall grass, sedges, rushes
no
6830 Collective code for tall herb community and alluvial meadows (3220/3960/6430/6450)
continue
Above coniferous tree line
yes
Key 5 Alpine areas
no
Dominated by tall herbs
yes
6430 Tall herb communities
no
Grass dominated alluvial shores affected by flooding along rivers with natural flow regime
yes
6450 Alluvial meadows

3.2.3 Key 3 Ocean, lakes and watercourses

This key entails both marine and limnic waterbodies. For the marine types the boundary against terrestrial habitat types is drawn at the mean water level. The area between the mean water level and the mean high water level are where the seashore habitats exist. The limnic types, such as AI *3210 Fennoscandian natural rivers,* include the shore and are therefore delineated at the mean high water level, with the exception of cases when these shores are described by other classes such as AI *6430 Tall herb communities* or AI *6450 Alluvial meadows*. The most frequently used AI classes from this key are 1000 and 3000 has these comprise a large proportion of the sampled area. The third most frequent class from this key is AI *3210 Fennoscandian natural rivers* which is described in more detail below.

Example AI class– 3210 Fennoscandian natural rivers

This class includes large rivers that is not significantly affected by regulation and has a near natural flow regime. Fennoscandian natural rivers occur in both boreal and alpine region. The water level shows great amplitude, up to 6 m during the year. Especially during spring, the water level is high. The river should have yearly water movement of > 20 m^3/s and is normally > 1 meter deep. As no additional data is used in MOTH, the interpreter recognises the rivers by being > 6 meters and >1 m deep and having a near natural water movements. A sampling point is given the class 3210 when it hits the water part or the shore, below the mean high water level of a river. In cases when the sampling point falls on a river shore that is a AI *6450 Alluvial meadow*, or AI *6430 Tall herb communities* these are given precedence before AI *3210 Fennoscandian natural rivers*.



Note small island or islet N_IS
This note is used in cases when the point falls on a smaller island or islet that is generalized to the surrounding water (1000 or 3000) because it is smaller than the minimum mapping unit (<0,1 ha).

N_IS

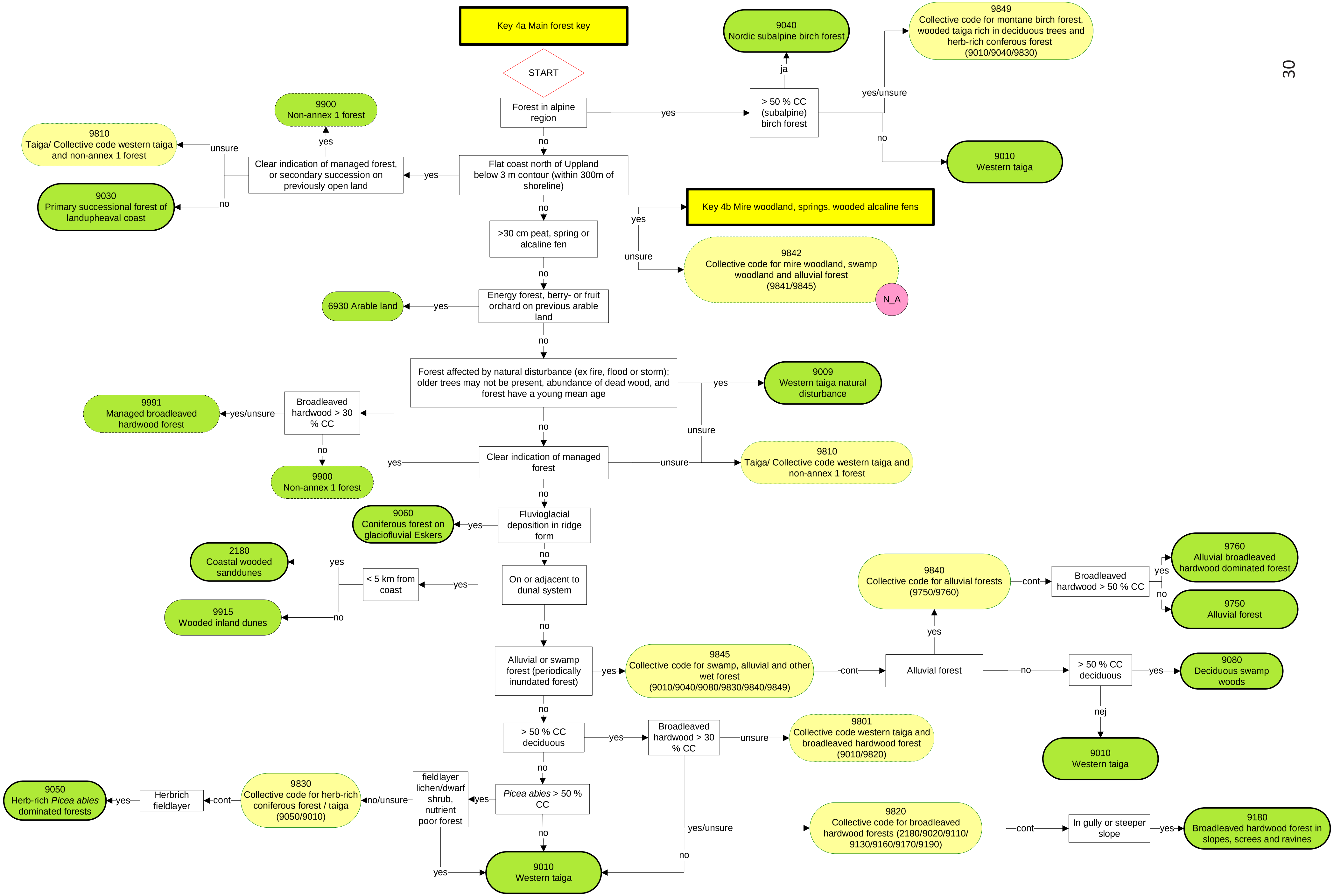
3.2.4 Key 4a Main forest key

This key is the largest amongst the classification keys used in MOTH, containing approximately 23 AI codes. It includes all forest types that are classified, except for forest growing on peat, such as mire woodland and similar habitats that are found in Key 4b. A forest should have a crown cover of trees > 10 % when classified according to our system. The most common AI-class used during the MOTH years has been 9900, which is non-annex 1 forest. Naturalness criteria for forest involve natural regeneration, presence of dead wood, absence of large scale forestry actions as well as age criteria. Structural aspect such as dead wood is often difficult to see in aerial images, except for standing dead wood. However, the interpreter can get an idea of remaining criteria through variables such as height, structure and colour of the forest. The older, naturally generated forest has a relatively uneven structure, is darker in colour and has higher trees relative to a planted forest with a younger age.

Example AI class– 9050 Herb-rich Picea abies dominated forest

Annex 1 habitat *9050 Herb-rich Picea abies dominated forest* in is a nutrient rich forest growing mainly in mesic conditions. This forest type can often be found in gullies or slopes where there is movement of groundwater. The field layer is rich in herbs due to the nutrient rich conditions. These forests are often species rich and may have many deciduous components. The production and growth rates in this forest are higher here compared to the more nutrient-pour conditions of for example Taiga. The tree height and density in *Herb-rich Picea abies dominated forest* is for this reason often relatively high.

In CIR aerial photo identification is primarily based on domination of spruce (> 50 % crown cover), the location in the terrain and signs of herb richness in the field layer. However, due to the difficulty of recognizing herb-rich field layer in a dense forest coupled with absence of additional data, the interpreter often cannot use the code AI *9050 Herb-rich Picea abies dominated forest* with any certainty. Instead, for most situations where spruce dominates the AI-code *9830 Collective code for herb-rich spruce forest/ Taiga (905079010)* is used. In locations where the interpreter is certain that the field layer is not rich in herbs because of evident lichen and dwarf-scrub dominance, the interpreter classifies the point AI-*9010 Taiga*. Conversely, AI-*9050 Herb-rich Picea abies dominated forest* can be used in situations the interpreter sees clear indications of herb-rich forest.

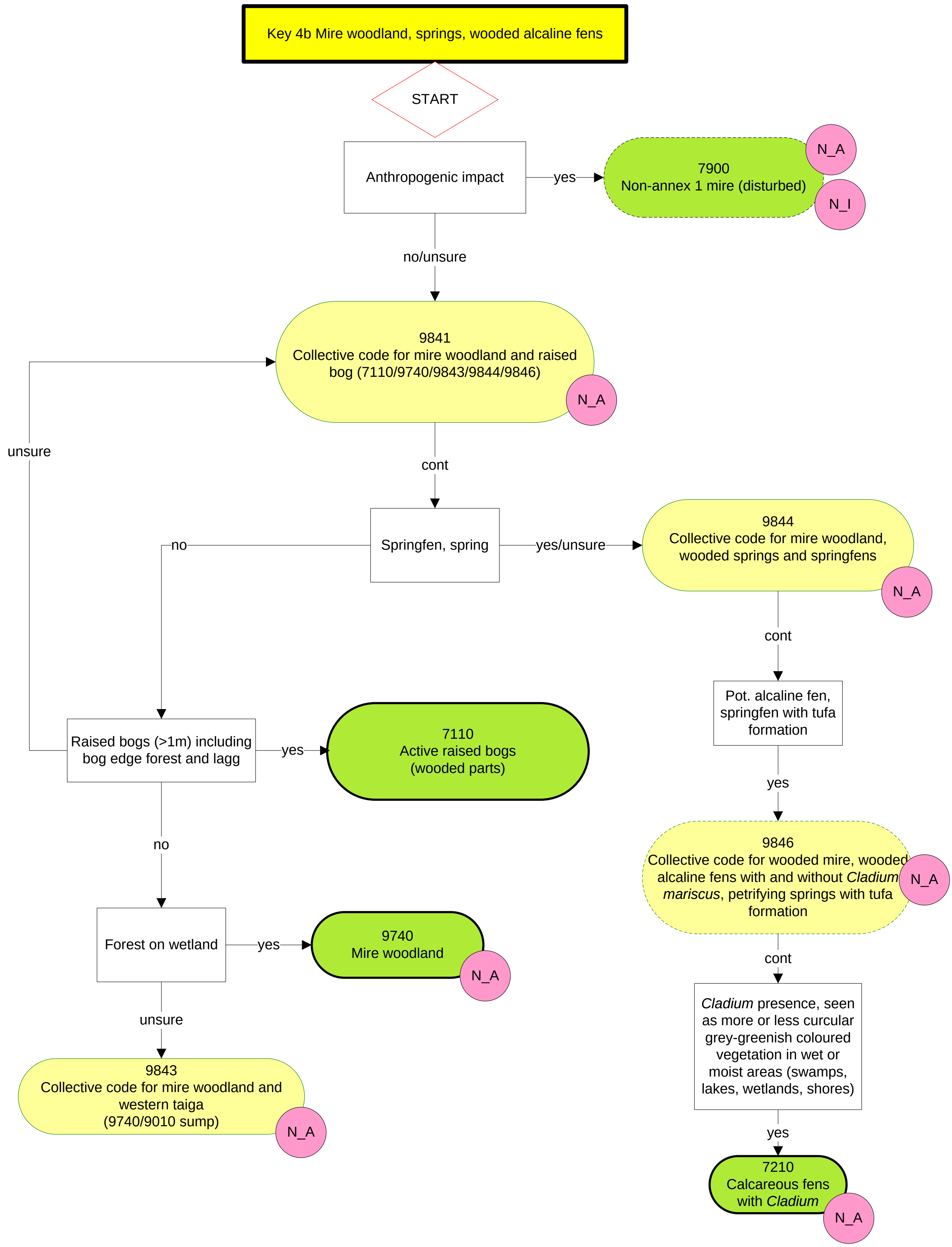

Key 4a Main forest key
START
Forest in alpine region
yes
> 50 % CC (subalpine) birch forest
ja
9040 Nordic subalpine birch forest
yes/unsure
9849 Collective code for montane birch forest, wooded taiga rich in deciduous trees and herb-rich conferous forest (9010/9040/9830)
no
9010 Western taiga
no
Flat coast north of Uppland below 3 m contour (within 300m of shoreline)
yes
Clear indication of managed forest, or secondary succession on previously open land
yes
9900 Non-annex 1 forest
unsure
9810 Taiga/ Collective code western taiga and non-annex 1 forest
no
9030 Primary successional forest of landupheaval coast
no
>30 cm peat, spring or alcaline fen
yes
Key 4b Mire woodland, springs, wooded alcaline fens
unsure
9842 Collective code for mire woodland, swamp woodland and alluvial forest (9841/9845)
N_A
no
Energy forest, berry- or fruit orchard on previous arable land
yes
6930 Arable land
no
Forest affected by natural disturbance (ex fire, flood or storm); older trees may not be present, abundance of dead wood, and forest have a young mean age
yes
9009 Western taiga natural disturbance
unsure
no
Clear indication of managed forest
unsure
9810 Taiga/ Collective code western taiga and non-annex 1 forest
yes
Broadleaved hardwood > 30 % CC
yes/unsure
9991 Managed broadleaved hardwood forest
no
9900 Non-annex 1 forest
no
Fluvioglacial deposition in ridge form
yes
9060 Coniferous forest on glaciofluvial Eskers
no
On or adjacent to dunal system
yes
< 5 km from coast
yes
2180 Coastal wooded sanddunes
no
9915 Wooded inland dunes
no
Alluvial or swamp forest (periodically inundated forest)
yes
9845 Collective code for swamp, alluvial and other wet forest (9010/9040/9080/9830/9840/9849)
cont
Alluvial forest
yes
9840 Collective code for alluvial forests (9750/9760)
cont
Broadleaved hardwood > 50 % CC
yes
9760 Alluvial broadleaved hardwood dominated forest
no
9750 Alluvial forest
no
> 50 % CC deciduous
yes
9080 Deciduous swamp woods
nej
9010 Western taiga
no
> 50 % CC deciduous
yes
Broadleaved hardwood > 30 % CC
unsure
9801 Collective code western taiga and broadleaved hardwood forest (9010/9820)
yes/unsure
9820 Collective code for broadleaved hardwood forests (2180/9020/9110/ 9130/9160/9170/9190)
cont
In gully or steeper slope
yes
9180 Broadleaved hardwood forest in slopes, screes and ravines
no
no
Picea abies > 50 % CC
yes
fieldlayer lichen/dwarf shrub, nutrient poor forest
no/unsure
9830 Collective code for herb-rich coniferous forest / taiga (9050/9010)
cont
Herbrich fieldlayer
yes
9050 Herb-rich Picea abies dominated forests
yes
no
9010 Western taiga

3.2.5 Key 4b Mire woodland, springs, wooded alcaline fens

Key 4b contains forest classified in MOTH that is growing on peat. It includes mire woodlands as well as wooded springs and spring fens. Presence of peat layer is relatively easy to identify in CIR images especially for larger mire complexes. However, the transition towards solid ground can be difficult to determine. Similarly, thin peat layers in alpine mires and some springs and spring fens are sometimes difficult to see in a CIR image. Nonetheless, all forest growing on peat are characterized by more or less impeded growth conditions in CIR image seen as sparse growth pattern and low tree height. This key also contains the code for disturbed mire, AI *7900 Non-annex 1mire*, that is used for all points that are affected by an anthropogenic activity of some sort (types of anthropogenic impacts are discussed in section 3.1.2 and listed in Appendix 1).

Example AI class– 9740 Mire woodland

Tree species composition varies in this AI class, including pine, spruce and birch. Peat layer is over 30 cm deep and is often dominated by *Sphagnum* species. Peat layer depth is not possible to measure in an aerial photo, but these mires can be identified by the evenness of the ground and tree crown layer, together with the colour indicators for wet ground that is reasonably clear in an aerial photo. Furthermore, the tree layer height is low and the forest generally sparse. Like in other mire classes it is relatively easy to recognize mire conditions, but the transition to solid ground can be difficult to delineate. For such situations of uncertainty there are numerous collective codes to use, encompassing wet forest and peat forest types as well as forest on solid ground, for example AI *9843 Collective code for mire woodland and western taiga (9740/9010).*


Key 4b Mire woodland, springs, wooded alcaline fens
START
Anthropogenic impact
yes
7900
Non-annex 1 mire (disturbed)
N_A
N_I
no/unsure
9841
Collective code for mire woodland and raised bog (7110/9740/9843/9844/9846)
N_A
unsure
cont
Springfen, spring
no
yes/unsure
9844
Collective code for mire woodland, wooded springs and springfens
N_A
cont
Pot. alcaline fen, springfen with tufa formation
Raised bogs (>1m) including bog edge forest and lagg
yes
7110
Active raised bogs
(wooded parts)
yes
9846
Collective code for wooded mire, wooded alcaline fens with and without *Cladium mariscus*, petrifying springs with tufa formation
N_A
no
Forest on wetland
yes
9740
Mire woodland
N_A
cont
Cladium presence, seen as more or less curcular grey-greenish coloured vegetation in wet or moist areas (swamps, lakes, wetlands, shores)
unsure
9843
Collective code for mire woodland and western taiga
(9740/9010 sump)
N_A
yes
7210
Calcareous fens with *Cladium*
N_A

3.2.6 Key 5 Alpine areas

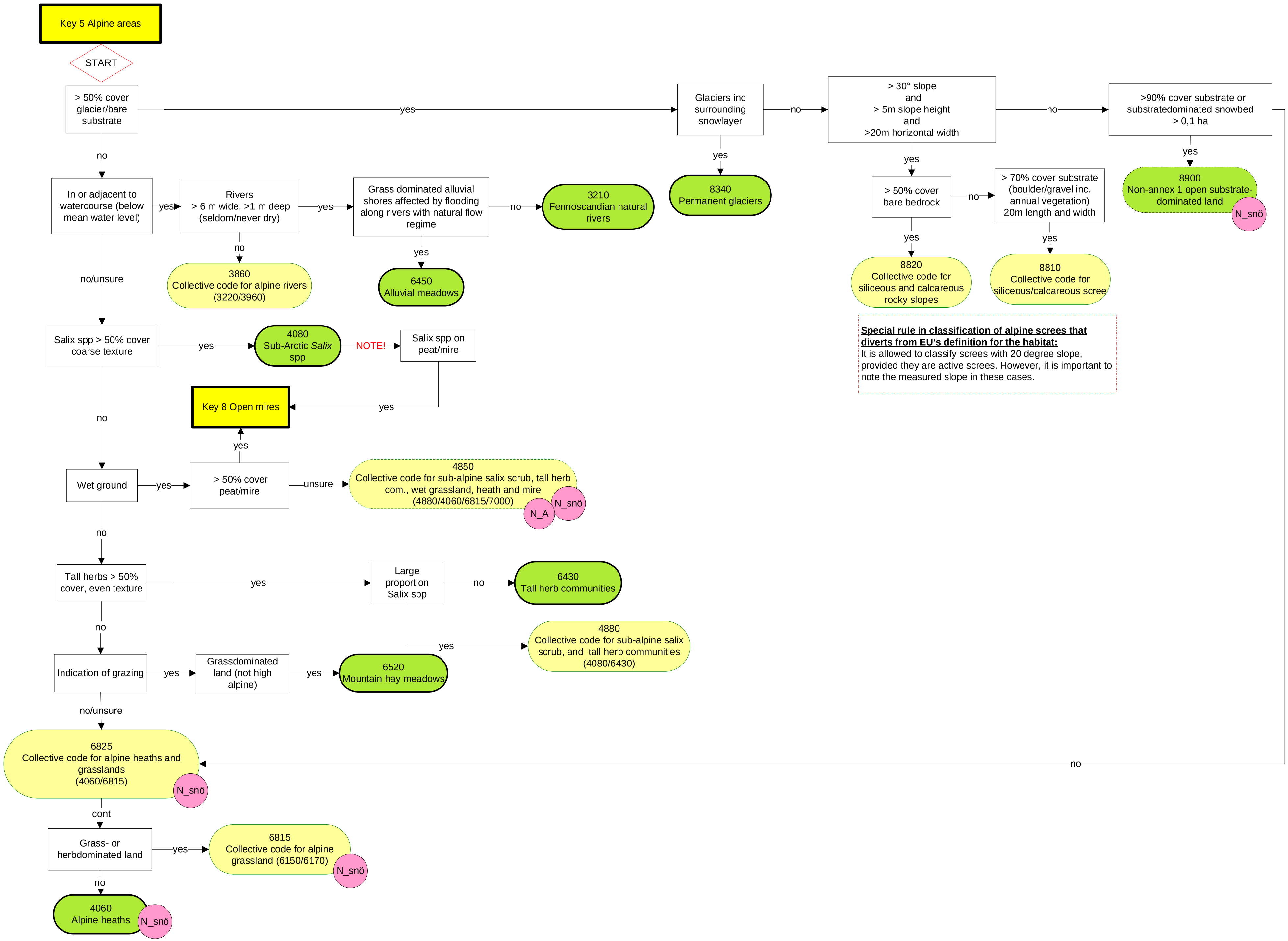
This key contains all AI classes in the alpine region except the forest or mire types that occur in the forest and mire keys. Thus, key 5 contain treeless (< 10% CC) habitats not occurring on peat. The most common habitat type in the alpine region is AI *4060 Alpine heaths* where dwarf shrubs dominate the vegetation. Grass dominated heaths are classified but no attempt is made at separating siliceous and calcareous types as this feature is impossible to identify in an aerial photograph. Instead AI *6815 Collective code for alpine grasslands (6150/6170)* is used. Grasslands in lower alpine regions that have indications of grazing would be classified AI *6520 Mountain hay meadows*.

In the alpine area *Salix* dominated communities grow throughout the ecotone from wet to dry areas. Interpreters identify *Salix* shrub communities relatively well, however when Salix co-occur with heaths rich in dwarf birch, which is common on AI class *4060 Alpine heaths* it is often difficult to determine which species dominate in the matrix. *Salix* is also common on peat forming ground and it can be difficult to separate AI *4080 Sub-arctic Salix communities* from AI mire classes. As a consequence, within the AI-class 4080 the three Annex 1 habitat types 4060, 4080 and 7140 are likely to be found. These are also combined in the wide AI collection code *4850 Collective code for sub-alpine Salix scrub, tall herb com., wet grassland, heath and mire.*

The patchy distribution of many alpine habitats poses classification problems for the aerial photo interpreter, as transitions may be difficult to determine. However, when the interpreter can determine the vegetation type in one patch, the general rule is that many small patches can be combined in alpine areas in order to fulfill MMU requirements.

Example AI class– 4060 Alpine heaths

This is the most common habitat type in the alpine region and comprises areas dominated by different species of dwarf shrub often intermingled with dwarf birch and *Salix* species. The ground cover consists of varying abundance of mosses and lichen depending on ground moisture. Because this AI class encompasses calcareous as well as siliceous areas and soil moisture varies from wet to dry, it includes a wide range of species assemblages. For this reason the texture and appearance varies in the aerial photo, from the relatively even dry heath to the much more uneven wet parts that form a transition to mire. Colour nuances vary from dark brown/red for the *Calluna* heath (see fig. 8:48b in Ihse *et al.* 1993), light-brown/red-brown *Empetrum* heath, "coniferous-coloured" *Juniperus* dominated heaths to bluish for the dry lichen rich heaths. Interpreters can identify alpine heaths quite well in an aerial photo as they stand out from the much more clear red found in the grass dominated habitats or the tall herb communities. But in transition towards other types and/or patchy occurrences this type may be difficult to separate from *Salix* communities, mire and/or alpine grasslands. In these cases AI *4850 Collective code for sub-alpine Salix scrub, wet grassland, heath and mire* and AI *6825 Collective code for alpine heaths and grasslands* are appropriate codes to use.



Key 5 Alpine areas
START
> 50% cover glacier/bare substrate
yes
no
Glaciers inc surrounding snowlayer
8340 Permanent glaciers
> 30° slope and > 5m slope height and >20m horizontal width
>90% cover substrate or substratedominated snowbed > 0,1 ha
8900 Non-annex 1 open substrate-dominated land
N_snö
> 50% cover bare bedrock
> 70% cover substrate (boulder/gravel inc. annual vegetation) 20m length and width
8820 Collective code for siliceous and calcareous rocky slopes
8810 Collective code for siliceous/calcareous scree
Special rule in classification of alpine screes that diverts from EU's definition for the habitat:
It is allowed to classify screes with 20 degree slope, provided they are active screes. However, it is important to note the measured slope in these cases.
In or adjacent to watercourse (below mean water level)
Rivers > 6 m wide, >1 m deep (seldom/never dry)
Grass dominated alluvial shores affected by flooding along rivers with natural flow regime
3210 Fennoscandian natural rivers
3860 Collective code for alpine rivers (3220/3960)
6450 Alluvial meadows
no/unsure
Salix spp > 50% cover coarse texture
4080 Sub-Arctic *Salix* spp
NOTE!
Salix spp on peat/mire
Key 8 Open mires
Wet ground
> 50% cover peat/mire
unsure
4850 Collective code for sub-alpine salix scrub, tall herb com., wet grassland, heath and mire (4880/4060/6815/7000)
N_A
Tall herbs > 50% cover, even texture
Large proportion Salix spp
6430 Tall herb communities
4880 Collective code for sub-alpine salix scrub, and tall herb communities (4080/6430)
Indication of grazing
Grassdominated land (not high alpine)
6520 Mountain hay meadows
6825 Collective code for alpine heaths and grasslands (4060/6815)
cont
Grass- or herbdominated land
6815 Collective code for alpine grassland (6150/6170)
4060 Alpine heaths

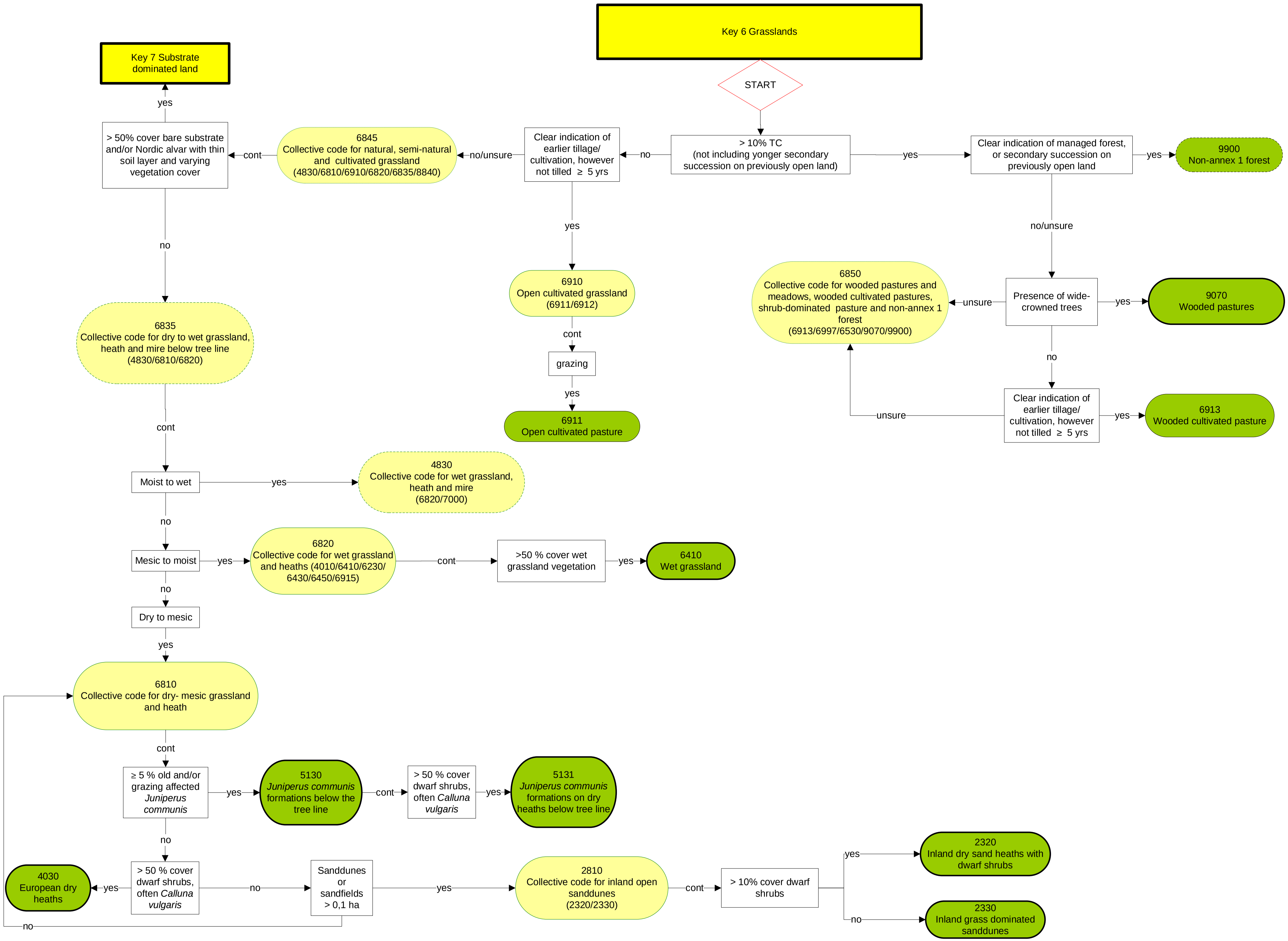
3.2.7 Key 6 Grasslands

Key number 6 contains non-alpine areas dominated by grass and/or shrubs that are kept open by some type of disturbance, in most cases grazing. One exception is AI *9070 Wooded pasture* that has a crown cover of trees > 10 % but is grazed by domestic animals. As Annex 1 grassland habitat types mainly are separated from each other based on species composition, they are impossible to distinguish in an aerial photo. However, the interpreter can identify indications of different types of anthropogenic management and differentiate moisture levels of grasslands. Because of this the key is organized mostly on the basis of management and moisture gradients. Because of this the key is organized mostly on the basis of management and moisture gradients. For example, AI *6810 Collective code for dry- mesic grassland and heath* entails all Annex 1 types that occur on dry to mesic ground and AI *6820 Collective code for moist/wet grassland and heaths* contains the wetter types whereas for situations with peaty influences AI *4830 Collective code for moist/wet grassland*, *heath and mire* is suitable to use.

The criteria of naturalness for Annex 1 grasslands is include presence of grazing or meadowland management and absence of recent tilling and use of fertilizers. Non-annex 1 grasslands can therefore be identified in an aerial photo through ploughing contours and an even and boulder-free grassed surface. When ploughing contours are evident and recent (< 5years) the area is classified AI *6930 Arable land*. Also, many have been croplands (> 5 years since tillage) that are today used for grazing have lost their conservation value due to agricultural practices and cannot be given Annex 1 classification. These areas are classified AI *6910 Open cultivated grassland*, which is a non-annex 1 AI code. In situations where the interpreter is unsure of the nature of anthropogenic management the AI code *6845 Collective code for natural and semi-natural grasslands and cultivated grassland (4830/6810/6910/6820/6835/8840)* is suitable to use.

Example AI class– 6810 Collective code for dry- mesic grassland and heath

This is a collective code for all dry to mesic semi-natural grasslands and heaths that are classified in the MOTH system. The semi-natural grassland/heath is kept open by grazing or meadowland management and is normally characterized by an uneven structure, often with boulders visible in the aerial photo (see fig 8:20 in Ihse, *et al*.1993). These grasslands and heaths also commonly have richness in shrubs depending on grazing pressure. This collective code includes a variety of grassland and heath types and can therefore include a vide spectra of colour nuances in CIR aerial photos, from light blue tinge in the dryer types to pink/red for the mesic grasslands and dark red/brown tone of the heaths. This AI code is thus primarily recognized through structures and texture that indicate traditional management and by soil moisture levels.


Key 6 Grasslands
START
> 10% TC
(not including yonger secondary succession on previously open land)
Clear indication of managed forest, or secondary succession on previously open land
9900
Non-annex 1 forest
Presence of wide-crowned trees
9070
Wooded pastures
6850
Collective code for wooded pastures and meadows, wooded cultivated pastures, shrub-dominated pasture and non-annex 1 forest
(6913/6997/6530/9070/9900)
Clear indication of earlier tillage/ cultivation, however not tilled ≥ 5 yrs
6913
Wooded cultivated pasture
Clear indication of earlier tillage/ cultivation, however not tilled ≥ 5 yrs
6910
Open cultivated grassland
(6911/6912)
grazing
6911
Open cultivated pasture
6845
Collective code for natural, semi-natural and cultivated grassland
(4830/6810/6910/6820/6835/8840)
> 50% cover bare substrate and/or Nordic alvar with thin soil layer and varying vegetation cover
Key 7 Substrate dominated land
6835
Collective code for dry to wet grassland, heath and mire below tree line
(4830/6810/6820)
Moist to wet
4830
Collective code for wet grassland, heath and mire
(6820/7000)
Mesic to moist
6820
Collective code for wet grassland and heaths (4010/6410/6230/ 6430/6450/6915)
>50 % cover wet grassland vegetation
6410
Wet grassland
Dry to mesic
6810
Collective code for dry- mesic grassland and heath
≥ 5 % old and/or grazing affected *Juniperus communis*
5130
Juniperus communis formations below the tree line
> 50 % cover dwarf shrubs, often *Calluna vulgaris*
5131
Juniperus communis formations on dry heaths below tree line
> 50 % cover dwarf shrubs, often *Calluna vulgaris*
4030
European dry heaths
Sanddunes or sandfields > 0,1 ha
2810
Collective code for inland open sanddunes
(2320/2330)
> 10% cover dwarf shrubs
2320
Inland dry sand heaths with dwarf shrubs
2330
Inland grass dominated sanddunes
yes
no
cont
no/unsure
unsure

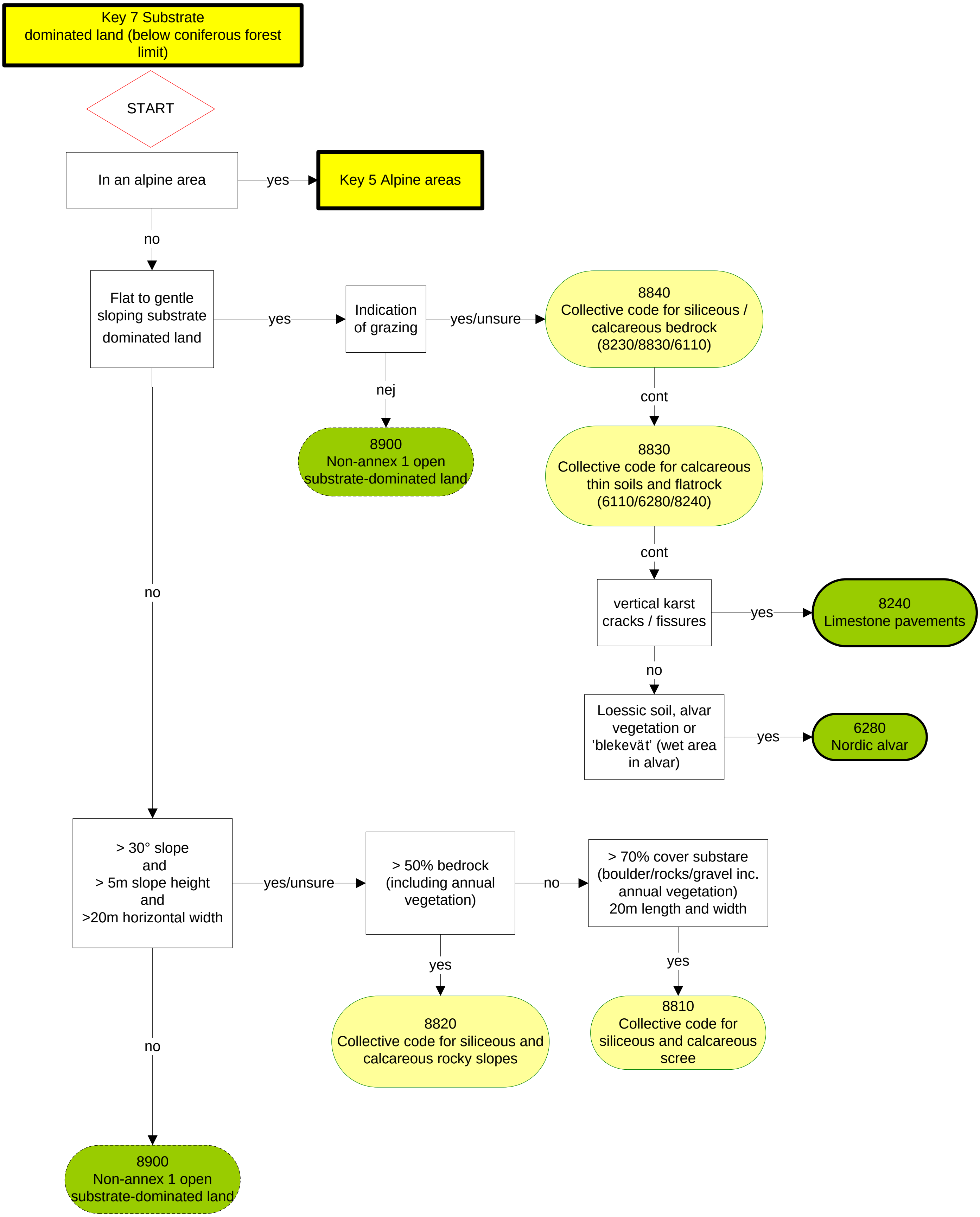
3.2.8 Key 7 Substrate

This key entails areas with 50% or more coverage of bare substrate which includes a wide range of biotopes. Rocky slopes and screes need to have > 30 degree slope to be classified in this system. However, it is allowed to classify screes AI *8810 Collective code for siliceous and calcareous scree* with 20 degree slope, provided they are active screes. In these cases it was important to make a comment about the size of the measured slope.

As there is no way to distinguish calcareous from siliceous ground these are classified with a collective code, e.g. AI *8820 Collective code for siliceous and calcareous rocky slopes*. Grazed substrate dominated areas displaying thin soils and flatrock are classified AI *8830 Collective code for calcareous thin soils and flatrock (6280/8240/6110)* and for other grazed substrate dominated land AI *8840 Collective code for siliceous and calcareous bedrock* can be used. Remaining substrate dominated land that is not sloping and is not grazed is given the AI code *8900 Non-annex 1 open substrate-dominated land*.

Example AI class– 8810 Collective code for siliceous and calcareous scree

Screes are formed through natural erosion processes. Large areas in the scree (>70%) are devoid of vegetation (may include some annual vegetation) as an effect of sliding rock and snow slides. The slope of scree should (in at least 50% of the polygon) be 30 degrees or more to be classified as Annex 1 habitat, however in MOTH screes were classified AI 8810 down to 20 degrees providing that they were considered active. For screes with slopes< 30 degrees, the slope was recoded to enable sorting out the "true" Annex 1 screes when reporting about the habitat. Screes are relatively easy to recognise in an aerial photo due to the steep slopes, with the bluish colour given by rock and the structure given by boulders.


Key 7 Substrate dominated land (below coniferous forest limit)
START
In an alpine area
yes
Key 5 Alpine areas
no
Flat to gentle sloping substrate dominated land
yes
Indication of grazing
yes/unsure
8840
Collective code for siliceous / calcareous bedrock
(8230/8830/6110)
nej
8900
Non-annex 1 open substrate-dominated land
cont
8830
Collective code for calcareous thin soils and flatrock
(6110/6280/8240)
cont
vertical karst cracks / fissures
yes
8240
Limestone pavements
no
no
Loessic soil, alvar vegetation or 'blekevät' (wet area in alvar)
yes
6280
Nordic alvar
> 30° slope
and
> 5m slope height
and
>20m horizontal width
yes/unsure
> 50% bedrock (including annual vegetation)
no
> 70% cover substare (boulder/rocks/gravel inc. annual vegetation)
20m length and width
yes
yes
8820
Collective code for siliceous and calcareous rocky slopes
8810
Collective code for siliceous and calcareous scree
no
8900
Non-annex 1 open substrate-dominated land

3.2.9 Key 8 Open mires

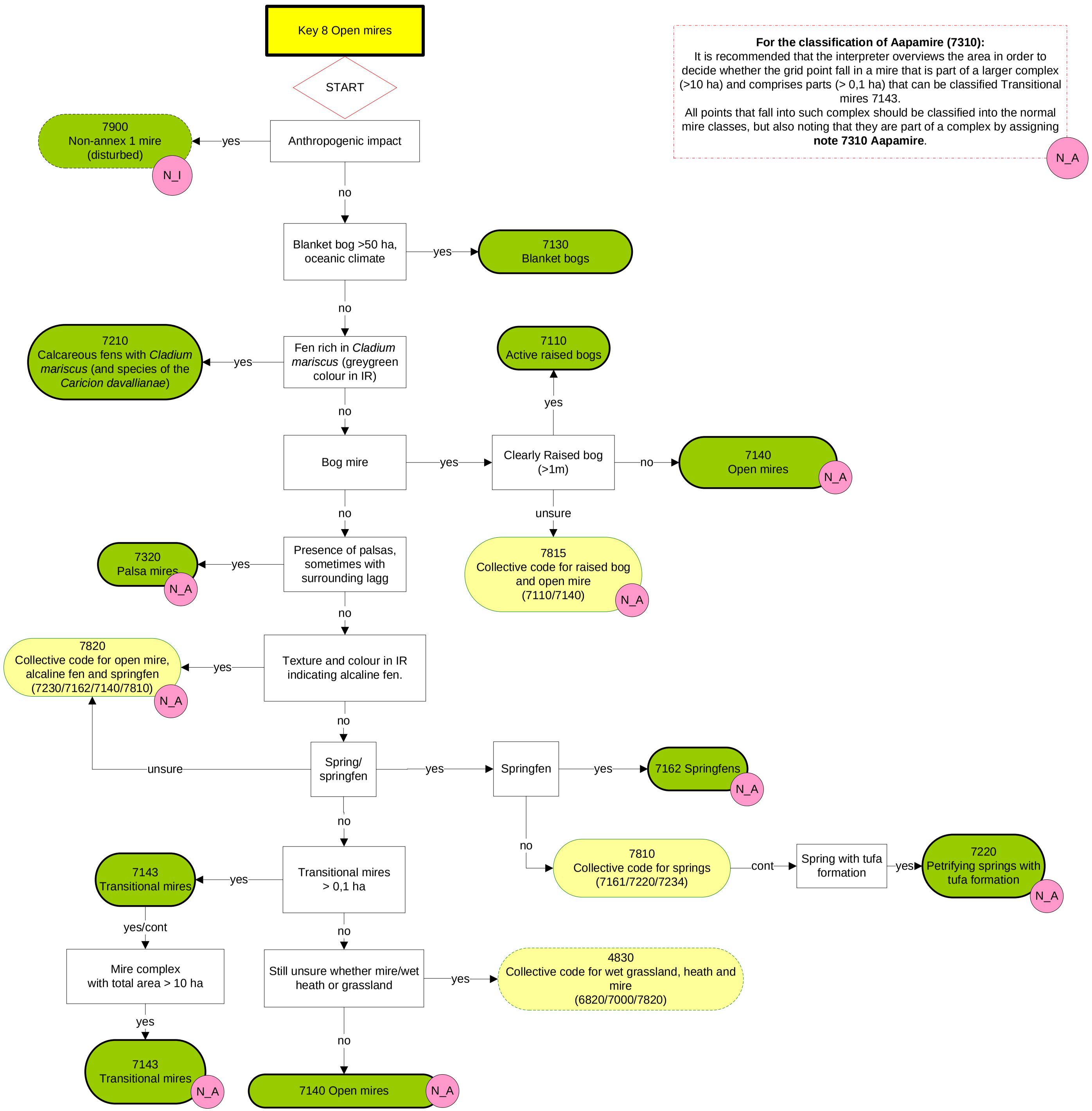
This is the key to mire types classified in MOTH including areas with 50 % coverage peat > 30cm deep. Presence of peat layer is relatively easy to identify in CIR images especially for larger mire complexes, although the actual depth cannot be measured. However, the more or less impeded growth conditions of vegetation, low tree height and sparse growth pattern, on and around the open mire are normally a good indicator of deep peat layer. While mire classifications within a large mire complex are relatively easy to make, the transition towards solid ground can be difficult to determine. Similarly, thin peat layers in alpine mires and some springs and spring fens are sometimes difficult to see in a CIR image. When these areas have tree crown cover > 10% collection codes can be found in Key 4b Mire woodland. Codes for unsure cases towards open habitats are found in the Key 6 Grassland or Key 5 Alpine key.

Certain large scale phenomenons are more easily identified in aerial photos than in the field. One example is the Annex 1 habitat *7310 Aapamires* , which are large mire complexes, containing multiple mire types (e.g. *9740 Wooded mire, 7140 Open mire, 7143 Transitional mire*) that together are larger than 10 ha. Characteristic for aapamires is also that they contain *transitional mire* areas (bog and fen parts formed as strings due to water movements). Due to the structural string-like features; AI *7143 Transitional mire* are easily recognized in an aerial photo. When classifying aapamires, the interpreter gives each point an AI mire class, but also gives the point a note AI 7310 Aapamire when falling within a complex.

The Annex 1 habitat *7110 Active raised bogs* are also better distinguished from above than from ground position, These are identified by the gently domed profile, with peat depth greatest in the centre (>1m) and then decreasing gradually towards the edges (Gardfjell & Hagner, 2014; SEPA, 2012;).

Example AI class– 7140 Open mire

This is a heterogeneous group of mires of both ombrogenous and soligenous types, in oligotrophic to mesotrophic water nutrient conditions. The ombrogenous bog is formed above the groundwater level and is dependent on rain for mineral nutrients. As a result these bogs have strongly acidic conditions where predominantly *Sphagnum* species and dwarf shrubs will grow. The even to weakly raised bogs are often plane without structures but sometimes exhibit structures such as strings, and waterparts obvious in the aerial photo. There may also be fen areas within the bog or surrounding the bog, then referred to as a lagg. The Annex 1 habitat *7140 Open mire* also include the minerotrophic fen, which has contact with the watertable and therefore receive nutrients from groundwater and is therefore less acidic than the bog. Vegetation is generally dominated by *Carex* species and fens generally have a greyish/blue colour in the aerial photo due to dead grass dominated vegetation and may also a hummocky structure.The certainty of identification in aerial photo is often good, except for distinguishing AI *7140 Open mire* from AI *7230 Alkaline fens*, which is difficult without additional data. In situations where the interpreter suspects alkaline fen, the code AI *7820 Collective code for open mire, alcaline fen and springfen* should be used. There is also a risk for misidentification towards AI *7110 Active raised bogs* as this requires measurement of a domed profile and for uncertainly in these situations the interpreter can use AI *7815 Collective code for raised bog and open mire.*



For the classification of Aapamire (7310):
It is recommended that the interpreter overviews the area in order to decide whether the grid point fall in a mire that is part of a larger complex (>10 ha) and comprises parts (> 0,1 ha) that can be classified Transitional mires 7143.
All points that fall into such complex should be classified into the normal mire classes, but also noting that they are part of a complex by assigning **note 7310 Aapamire**.

N_A

Anthropogenic impact on mire:
Diches/roads that have caused significant hydrological impact
Clear indication of managed forest
Peat extraction

Rules relating to distance to diches:
Mire grid-points with diches within 25 meters that have caused significant hydrological impact are classified 7900 Non Annex 1 mire.
Mire grid-points with a dich within 25 meters, where the interpreter can see that the dich have not had significant hydrological impact and the vegetation is unchanged from the rest of the mire, the point can be Annex 1 classified (but note the dich with code 719)
Mire grid-points with a dich within 25 meters, where the interpreter is ***unsure*** whether the dich has caused significant hydrological impact on the area, the point is classified 7900 Non Annex 1 mire.

Note N_I 719

Observe note **719 Diched mire** is used when classifying 7900 Non-annex 1 mire.

Also used when diches are seen within 25 meters from the point (but have not affected the vegetation of the point) when classifying an Annex 1 mire habitats.

Observe that 7900 is a better code to use when unsure of the dich hydrological impact.

4 Seashore Inventory Methodology

It is difficult to find clear definitions of the position where the seashore begins and ends as well as the position of a shoreline in literature, as these concepts vary in time and space. They are therefore often defined pragmatically to suit the situation in each study (Boak & Turner 2005). The seashore (also known as the intertidal or littoral zone) is the highly dynamic environment with fluctuating water levels that make up the ecotone between marine water and land. The *shoreline* can in an idealized way be described as the physical interface of land and water (Boak & Turner, 2005; Dolan *et al.,* 1980). However, the position of the shoreline changes continually through time due to shore sediment movement of the littoral zone, and the dynamic nature of water levels at the coastal boundary (Boak & Turner 2005; Smith & Zarillob, 1990).

The photo interpretation survey of the Swedish coastline uses a line-layer arranged as hexagons superposed on a colour infra-red aerial photos, which are studied in stereo view. The intersections between the line-segments and the shoreline are marked *at mean sea level* become the sampling points (Fig. 13). The mean sea level is defined as the average level (of high and low water levels) of the ocean's surface measured over a period of 30 years (SMHI). During photo interpretation, however, the mean sea level typically translates to the *actual interface between land and water in the photo instant*, as it normally is difficult to estimate whether or not the water levels seen in the aerial photo deviates from the mean sea level. However, the point is adjusted if the interpreter detects indications of extreme water levels in the aerial photograph.

Data sources used in the seashore inventory include:

- Recent aerial photographs over each sampling unit,
- The Property map of Sweden,
- The nationwide GSD Orthoimage (both in colour and CIR) provided by the National Land Survey,
- The jetty registry (Törnquist & Engdal, 2010) and
- Wave exposure data from SAKU (Wennberg & Lindblad, 2006).

Documents used during interpretation are the seashore classification workflow (Appendix 4) and instruction manual.

4.1 Working process aerial photo interpretation of point and transect

The interpreter normally works through the following stages described below when a new sampling unit is loaded in a workstation:

1) Place all the sampling points at the intersections between the hexagonal layer and the mean sea level.
2) Make a quick overview of the area to get an idea of what variables, if any, that can be "mass-classified" using ArcMap's tool "Field Calculator" (for example, variables that don't occur in the particular area and can therefore be classified in the attribute table without actually assessing this variable at each individual point)
3) Assess each sampling point:
    a. Draw the seashore transect from the point in the mean water line to the end of the supralittoral zone (section 4.1.1).
    b. Measure or assess relevant variables at each point
    c. Place a 0 for the variables that don't apply to the particular point

4) Place out points or lines for different exploitation types, in cases when exploitation occur closer to the sampling point than what is indicated in the property map or jetty registry (section 4.2.7).

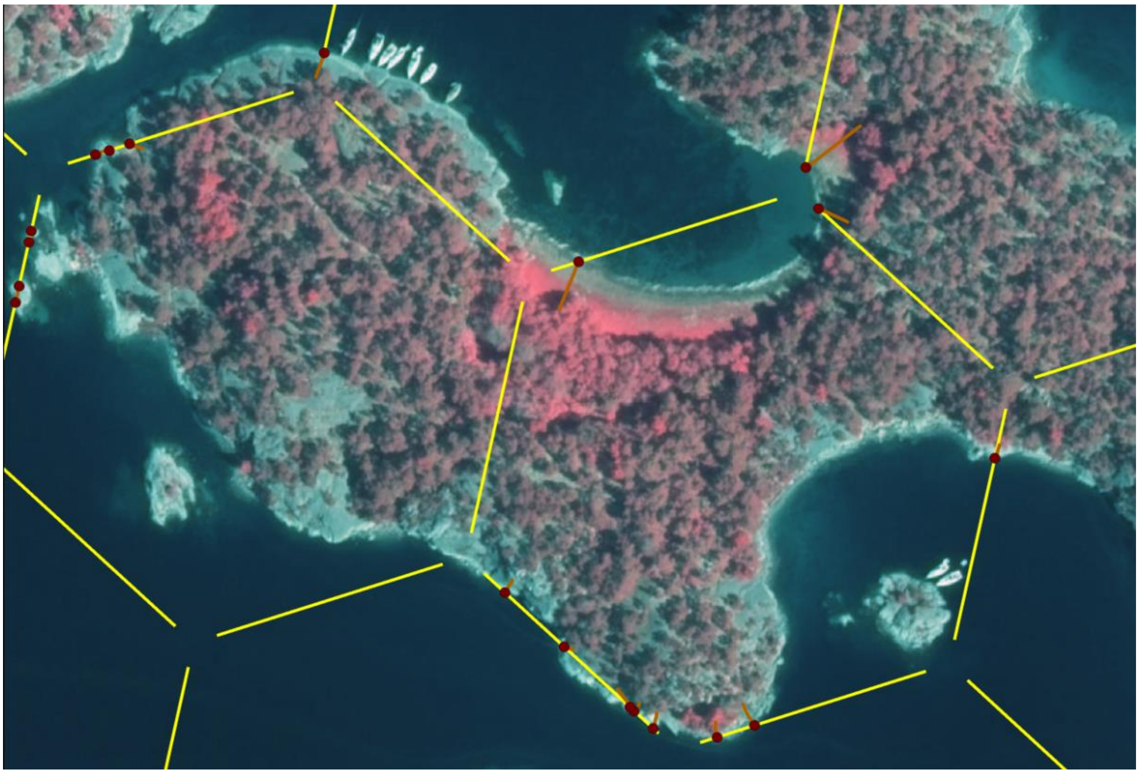


***Figure 13**: Sampling points, (in red) placed by a photo interpreter in sampling unit 3131, at the intersection between the yellow line segments of the hexagonal layer and the waterline. Note the shore transects drawn in brown are shorter on the steep cliffs and longer on the more gentle sloping shores of coastal meadows (CIR image provided by National Land Survey, 2013).*

4.1.1 Establishing the transect

The intersect point marks the starting point of the shore transect. The transect line is drawn perpendicular to the contour line, the steepest line, to the end of the supralittoral zone (Fig. 14). The identification of the end of the supralittoral zone is at times difficult. Indications of this point differ depending on the type on shore that is assessed:

- **Cliffs**: The different zones on a cliff that can be identified in the field are not all possible to see for the photo interpreter. However, the lichen that indicates the end of the supralittoral zone can often be discerned. Other indicators such as presence of grass, dwarf-shrubs can also be used. And for gentle sloping cliffs, drift lines can also indicate the end of the supralittoral zone.
- **Sand- gravel- boulder- and coastal meadow shores**: Usually the end point of the supralittoral is given by a shift in substrate and/or vegetation type. Drift lines can indicate to end of the supralittoral zone on these types of shores, and on shores with land upheaval forest the higher end of *Betula* and *Salix* vegetation can be a good indicator.
- **Sandy shores**: Usually the end point of the supralittoral is given by a shift in substrate and/or vegetation type. Furthermore, the end of the supralittoral zone is approximately at the beginning of the first sand dune with perennial vegetation (Hedenås, 2013), when these are present.

Ten meters either side of the transect line form the assessment area from which many classifications are made and variables are measured (Fig. 14). Some variables and classifications are measured beyond the transect line.

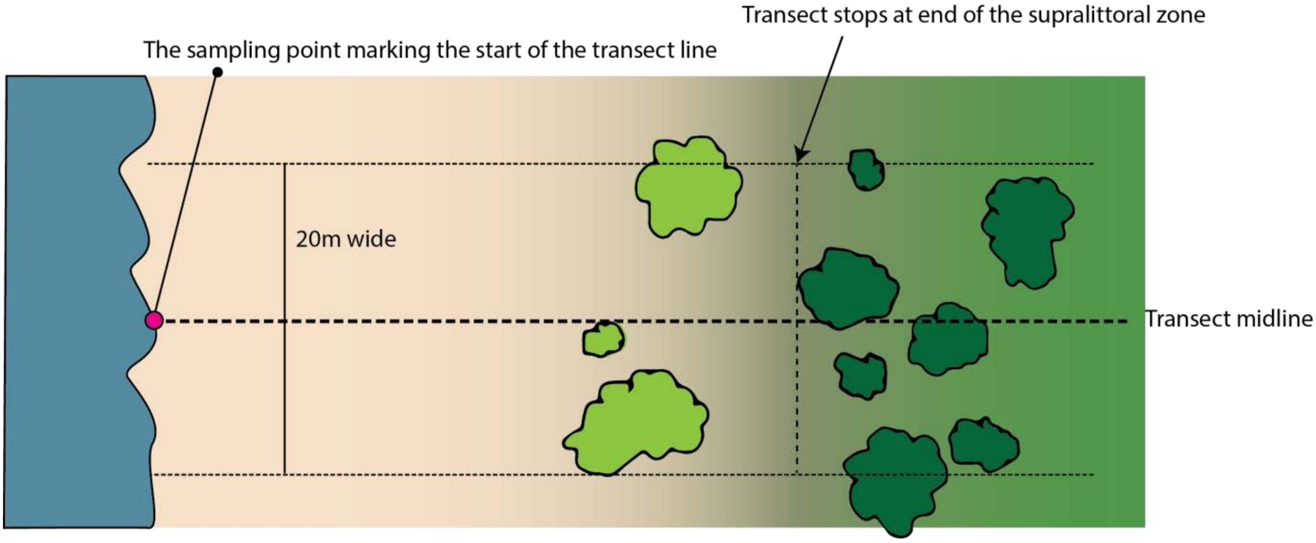


***Figure 14**: Illustration of the placement of a sampling point and transect line (modified from Hedenås, 2013). Shore-type is classified at the sampling point. Vegetation coverage (trees, shrubs, field layer) is measured within the 10 x 10 meter wide transect. Dominating land use and presence of saltpans is assessed within the transect area. Sand dunes, land upheaval forest, cliffs and boulder/gravel banks can occur both on and above the seashore and the total length of these are often measured beyond the end of the transect. Interpreters also assess land use above the seashore. Mud and sandflats as well as coverage of Phragmites are usually assessed below the sampling point, although the whole length of Phragmites belt is measured, which often includes area above the mean sea level (see Appendix 3 & 4 for more information on assessment areas for different variables).*

4.2 AI Classification scheme – Seashore habitat inventory

The degree of wave exposure largely determines the type of shore at any point of the Swedish shoreline, as it determines the conditions of sedimentation and erosion. Exposure to waves leads to erosion of finer particles leaving coarser fractions such as boulders and cliffs, whereas sedimentation of finer particles creating sandy shores and mudflats takes place at sheltered bays and inlets (Loberg 1980; SGU, 2012).

In the seashore inventory we follow a different AI classification scheme than the one used during the Terrestrial habitat inventory. Instead of using AI *habitat* classes we have used the knowledge that many Annex 1 habitats targeted in MOTH's seashore survey correlate well with broad substrate classes that are found as a result of different degrees of wave exposure. The core classification is therefore ***shore-type*** that identifies the potential presence of many targeted habitats (Table 4) and forms the basis for selection of field points (section 4.2.2). However, other habitats occur immediately above or both on/above the seashore (Appendix 3 & 4). These types are captured by other classifications (see section 4.2.5 & 4.2.6).

Table 4: *Annex 1 habitats and other targeted habitats occurring in MOTH Seashore inventory and the expected correlation with MOTH AI classes Shore type and Coast type, and with other classifications or measurements made during interpretation. Target habitats 1239 and 1952 are not listed in Annex 1. AI class Shore type is based on broad substrate classes whereas Coast type defines whether the seashore is situates on mainland or on islands in different size categories. X indicate that this class/variable form the basis of selection targeting the specific habitat, however not all Annex 1 habitats have a specific selection category.*

Code	Annex 1 habitat/target seashore habitats	Expected correlation with:		
		Shore type	**Coast type**	**Other variables**
1210	Drift lines			X
1220	Boulder- and gravel dominated banks			X
1230	Sea cliffs	X		
1239	Cliff shore	X		
1310	*Salicornia* seashores			X
1330	Atlantic coastal meadows	X		
1610	Baltic esker islands		X	
1620	Baltc islets		X	
1630	Baltic coastal meadows	X		
1640	Sandy shores	X		
1952	Boulder or gravel on land upheaval coast	X		
2110	Embryonic shifting dunes			X
2120	Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)			X
2130	Fixed coastal dunes with herbaceous vegetation (grey dunes)			X
2140	Decalcified fixed dunes with *Empetrum nigrum*			X
2170	Dunes with *Salix repens* ssp. *argentea* (*Salicion arenariea)*			X
2180	Wooded dunes of the Atlantic, Continental and Boreal region			X
2190	Humid dune slacks			X
9030	Primary successional forest of landupheaval coast			X

4.2.1 Coast-type

Coast-type defines whether the seashore is located on the mainland, on an island, islet or a shallow. Classification of this variable is relatively straightforward; however, the need to estimate island, islet and shallow area requires some attention. This variable is used (together with the forest variable for islands/islets) for the selection of treeless islets (1620). The class shallows are excluded from field selection as it is not practical to visit them in the field.

Table 5*: The classes within the variable coast-type used aerial photo interpretation.*

VARIABLE	CLASSES	ASSESSMENT AREA
Coast type	mainland	transect and point
	island (>2 ha)	
	islet (0,1-2 ha)	
	shallow (<0,1 ha)	
	esker island	

4.2.2 Shore-type

Shore-type allocates each intersection point in one of five broad substrate classes (Table 6, Fig. 15). The variable partitions sampling points based on grain size, where degree of wave exposure governs the size of the grain. From cliff/bedrock on the exposed shores to finer the particles like clay on the more sheltered shores. An aerial photo interpreter can distinguish between these classes well, (Table 7 & 8) as these features are quite evident when studying aerial photographs with 0, 5 meter resolution in stereo view. However, when shore-types are mixed at a sampling point (e.g. boulders and sand), the dominating shore-type class can be difficult to determine. Furthermore, dense vegetation can also make the shore-type classification more challenging, as the interpreter cannot see the substrate beneath. However, vegetation type may be an indicator in certain cases. For example, shores dominated by *Phragmites* are classified as coastal meadow/wetland unless there are clear indications of other substrate type.

Table 6*: The core classification made during aerial photo interpretation is shore-type, which places each sampling point in one of five substrate classes.*

VARIABLE	CLASSES	ASSESSMENT AREA
Shore type	cliff	at sampling point
	boulder/gravel	
	sand	
	coastal meadow/wetland	
	constructed/man-made	

Cliffs (Fig. 15 A) are recognised by their shape, their solid impression and hard surface. They can have a smooth to rough surface depending on the type of bedrock exposed and often have vegetation in crevices (Åkerholm, *pers. com.* 2015). While many zones on a cliff can be differentiated in the field, only certain can be seen in an aerial photo, for example the bare zone seen as a lighter rim closest to the waterline. Gravel/boulder dominated shores (Fig.15 B) have coarse structure sometimes with individual boulders visible especially out in the water close to the shoreline. Sandy shores (Fig. 15 D) appears much finer and have a smooth to almost velvety surface in a CIR aerial photos. While the colour nuances of substrates in all shore-types are different shades of grey/blueish, sand have the lightest grey of these and sometimes appear almost white. Coastal meadows/wetlands (Fig. 15 C) usually have high vegetation cover and the clay-rich substrate below is fine.

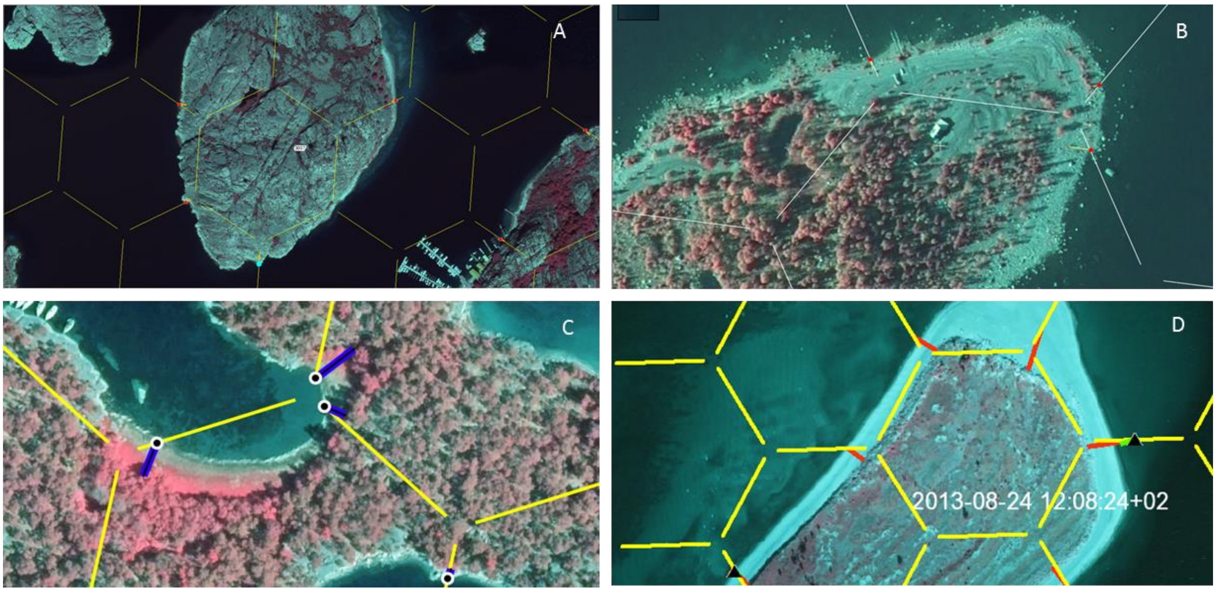


***Figure 15**: CIR images of four shore-types classified in the seashore inventory (CIR image provided by National Land Survey, 2013). Image A contains a cliff shore of a treeless island or islet. Image B illustrates shore-type boulder/gravel with gravel/boulder dominated banks on and above the shore. Image C illustrates shore-type coastal meadow in a sheltered bay. Image D illustrates shore-type sand, with sand dunes above the shore.*

Table 7 below illustrates how well the photo interpreted classification and the field classified variable shore-type correlate in the 2012 data. The concurrence is generally high (68-92%), with the boulder/gravel shore-type class having the lowest concurrence. The differences in classification here are probably related to the dominance problem discussed earlier, along with the fact that the exact position of the surveyed point will have great impact on shores with mixed shore-type classes.

***Tabell 7**: Shore type classified during aerial photo interpretation during 2012 season and corresponding field classification.*

SHORE TYPE (2012)				
Field:	**cliff**	**boulder/gravel**	**sand**	**coastal meadow**
AI:				
cliff	85%	7%	4%	4%
boulder/gravel	8%	68%	14%	10%
sand	0	8%	92%	0
coastal meadow/wetland	0	10%	7%	84%

Another way of illustrating this is how the variable AI shore-type is used is the way it correlates with field classified habitats (Table 8). The targeted habitats *1230 Sea cliffs* and *1239 Cliff shore* where in 92% of cases classified on transects classified as shore-type cliff by photo interpreters. *1640 Sandy shores* correlate quite well with AI shore-type sand (80%). The lowest correlation in the example in table 8, is for the coastal meadow types (1310, 1330 and 1630), where 60% were classified as coastal meadow by interpreters. Remaining AI coastal meadow classifications were mostly classified 9999 by field staff, indicating the area did not meet criteria of naturalness, which does not necessarily mean that the AI-class was incorrect (Table 8).

Table 8*: Relationship between AI shore-type and field habitat classified closest to the sampling point. Data from 2012 and 2013.*

First field habitat:	1230 1239	1220 1952	1640	1310 1330 1630	9999
AI_shore type:					
cliff	91,7%	2,8%		0,7%	4,9%
boulder/gravel	8,3%	71,3%	2,8%	7,4%	9,3%
sand		2,7%	79,7%	2,7%	14,9%
coastal meadow/wetland	1,1%	1,1%	1,1%	60,4%	36,3%
constructed					100%

4.2.3 Land use on and above the shore transect

The dominating land use on the shore is assessed within the 10 x 10 meter wide transect. The transect area can vary in size depending on what type of shore is assessed which affects the transect length. Therefore, this variable does not have any minimum mapping unit (MMU) requirements. Indications of land use and management are something that photo interpreters can identify better than any automatic technique available today. The classes and what these contain are listed below:

- **no apparent land use**: shores largely unaffected by human activities,
- **constructed/man-made**: physically altered shores such as piers, harbours, wharfs and jetties,
- **affected (residential/recreational)**: shores affected by human activates, although not physically altered, such as residential areas or shores heavily used for recreational activities,
- **grazing/mowing**: cattle grazing or mowing of natural coastal meadows
- **other**: motivated with comment by photo interpreter

The dominating land use above shore is assessed within a 0.1 ha large area immediately above the shore transect. The land use classes used here are the same as in the Terrestrial Habitat Inventory and can be found in table 2 in section 3.1.3.

4.2.4 Vegetation measurements

Vegetation coverage is assessed within the transect area (Fig. 14). Crown cover of trees as well as coverage of shrubs and field layer are measured, and classified according to the six classes listed below. As the transect length varies, so does the area of assessment. The interpretability of this variable also varies greatly depending on the situation at each shore.

Vegetation coverage classes:

0. 0 %
1. 1-5%
2. 6-10%
3. 11-30%
4. 31-70%
5. 71-100%

Phragmites measurement

The common reed is widespread and forms large belts when the nutrient conditions are favorable. We wanted to get an idea of how many shore transects were dominated by reeds and photo interpreters therefore measure the length of such belts in the seashore inventory. The measurement is made along the transect midline, meaning that when the reeds occur in tufts instead of belts, it is only the tufts intersected by the transect midline that are measured (Fig. 16). The combined length of the tufts constitutes the length measurement in such cases.

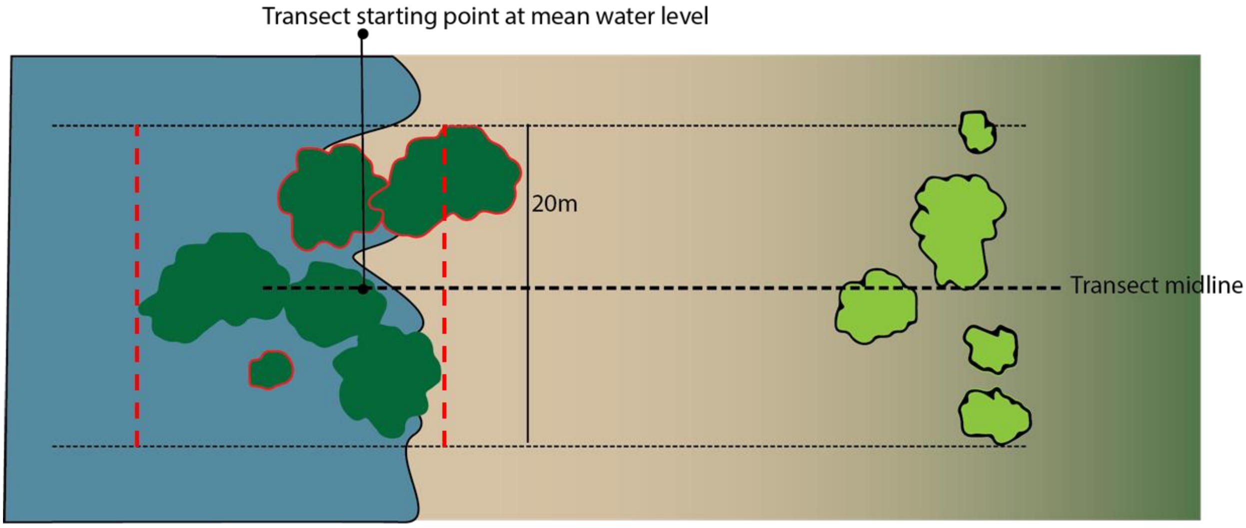


***Figure 16**: Illustration of measurement of reed during interpretation survey (modified from Hedenås, 2013). The length of reeds is measured along transect midline, and in case of tuft measurements,only the tufts intersected by the transect line are included in the measure. In the figure above the tufts with the red margins are not included in the length measure.*

4.2.5 Length of sand dunes, boulder/gravel banks and land upheaval forest

Presence of sand dunes, boulder/gravel dominated banks and land upheaval forests are all indicated by a length measurement. The length is measured perpendicular to the contour lines from the beginning of the habitat, which can be both on or above the shore transect, to the point where the habitat ends. This measuring line does not necessarily follow the same angle as the shore transect, however, the transect line needs to intersect the habitat in order for presence to be noted (Fig. 17 A).

The elevated topography of both sand dunes and gravel/boulder banks is relatively easy to identify in stereo view of aerial photos. To identify the substrate type the ridge is comprised of can be difficult, especially when the dunes or banks are covered with vegetation. In most cases however, substrate in the dunes or ridges correlate with the substrate type on the shore. Gravel/boulder dominated banks are recognized by the course structure of the substrate, arranged in ridge formations. They occur mostly in combination with shore-type boulder/gravel. They are tree-less and usually have some substrate dominated areas, although older banks can be dominated by vegetation (Fig. 17 B).

Sand dunes are recognized by the elevated dune formations, the fine sand grain and presence of varying degrees of stabilizing vegetation as well as the fact that sand dunes generally coincide with shore-type sand (Fig. 17 A). In this inventory we identify the end of the shore transect at the end of the supralittoral zone. On sandy shores this point coincides with the first sand dune with stabilizing vegetation. This is the point at which photo interpreters starts measuring dune length. While there is a range of dune types identified in the field inventory (according to definitions found in the Habitats Directive), photo interpreters do not attempt to differentiate between these. Instead the whole length of the dune complex is measured, including wooded dunes. However, in order to separate dunes with tree cover, percentage wooded dunes are also indicated when present (Appendix 3 & 4).

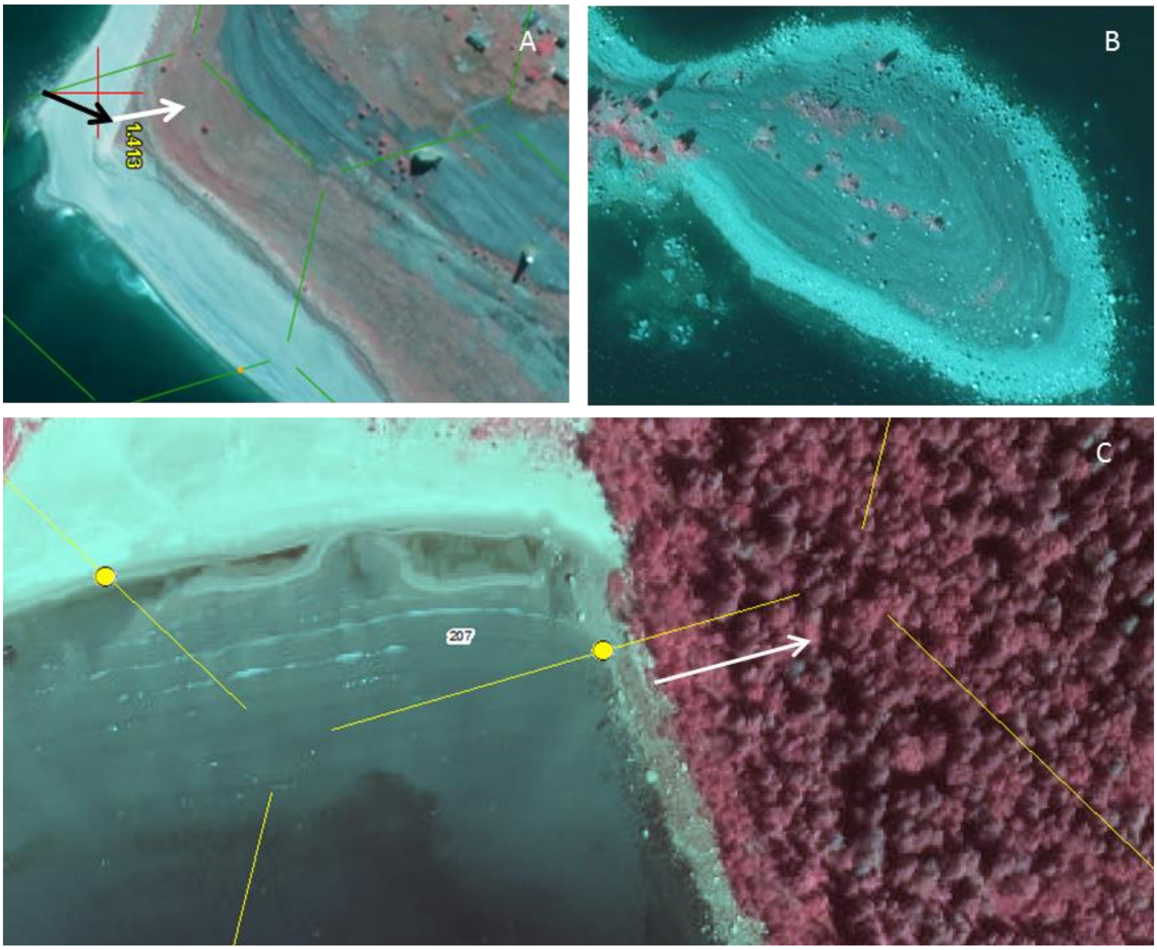


Figure 17: *Three CIR images illustrating features that photo interpreters register in the seashore inventory (CIR image provided by National Land Survey, 2013 and 2015). Image A illustrates shore-type sand, with dunes above the supralittoral zone, followed by gravel/boulder banks (beyond white arrow). Note that the line angles is not the same for the shore transect and the dune measuring line. Image B illustrates a boulder/gravel shore followed by the terraced boulder/gravel banks. The white arrow in image C indicates land upheaval forest. The starting point is visible in this image (at the outer border of the deciduous tree and shrub line), but to determine the end point the information from contours of the property map needs to be used.*

Land upheaval forest is a pioneer forest that colonizes shores where new land rises due to the post-glacial rebound. It occurs on land upheaval coast in Sweden, from northern Uppland and northwards along shores of the Gulf of Bothnia. Land upheaval forest typically occurs on gentle sloping shores and grows both on the shore and also above the shore. The upper limit of the forest type is at 3 m above the sea level and the lower limit is below the *Salix* shrub border. The lower parts of the forest generally comprise of deciduous species (*Salix*, *Betula*, *Sorbus* and *Alnus* species) that usually are replaced by coniferous species as we move above the supralittoral zone (Gardfjell and Hagner, 2013).

In photo interpretation the forest is recognized by the deciduous shrub and tree border often present on the shore (Fig. 17 C) together with location along the coast and the contour lines on the property map. However, in the southern part of this forest type distribution, the forest may be coniferous all the way to the shore. The interpreter also needs to assess whether the forest is affected by forestry activities as such forest is not included in the length measure.

4.2.6 Presence of drift-lines, mud- and sandflats, presence of accumulated salt/saltpans and lagoons.

During interpretation these features (drift-lines, mud- and sandflats accumulated salt/saltpans and lagoons) are indicated by noting presence or absence in the database. Some features such as mudflats and saltpans are registered because they indirectly indicate the presence of certain Annex 1 habitats targeted in this inventory. The drift-lines, more directly point at targeted Annex 1 habitats, however, they always need confirmation in the field for a classification to be made. While being an Annex 1 habitat lagoons have not been targeted in the seashore inventory, however, seashores along the edges of lagoons are registered with a note.

Drift-lines can be identified by a photo interpreter provided they are relatively coherent and not very small. They are recognized by their structure (stretches along the shoreline) and position on the shore (Fig. 18 A). Depending on drift-line age they may be covered with varying degrees of vegetation, from bluish colour of young drift to red nuances of the drift-lines with vegetation (Skånes *et. al.* 2007). From 2015 interpreters in the seashore inventory only register the presence of drift-lines when the shore transect intercepts on of these, and do not measure lengths as in previous years.

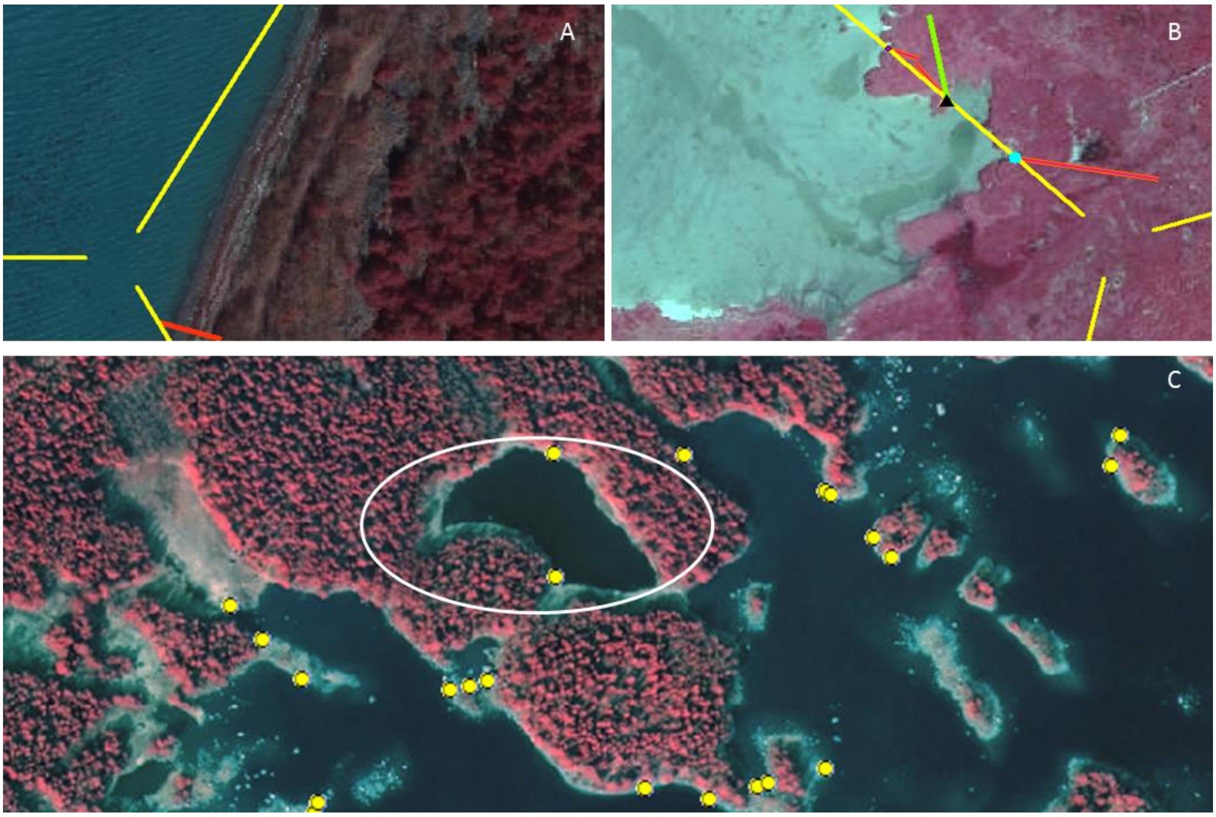


Figure 18*: Three CIR images illustrating features that photo interpreters register in the seashore inventory (CIR image provided by National Land Survey, 2013 and 2015). Image A illustrates a shore with drift-line (s), seen as the long-stretched structure with brown/red vegetation. Image B illustrates a coastal meadow with mudflats below the shoreline. Also on the shore are saltpans seen as dark depressions in the ground, which turn whitish as they dry. Image C illustrates what photo interpreters in this inventory have classified as lagoon (indicated with a white ring).*

Mud- and sandflats are shallows comprised mud to sand bottoms and are partly exposed during low water levels (Fig. 18 B). They lack large populations of vascular plats in the transition between sea and land and instead colonised by algae (European Commission, 2007, Swedish EPA, 2011). In this inventory the presence of mud and sandflats are classified < 3m below sea surface, and the assessment is somewhat uncertain as its dependent on the tidal position at the point in time of the aerial photograph (Skånes, 2007). In the seashore inventory we do not register pure sandflats or reefs. Water depth is not possible to measure in an aerial photograph, but the fact that the interpreter can see the bottom indicates shallow waters, usually < 3 meters (Allard, *pers. com.* 2015). To register presence, the visible shallow mud/sandflat needs to extend at least 10 meters from the mean water line. It should be noted that we do not intend to classify the Annex 1 habitat *1140 Mudflats and sandflats not covered by seawater at low tide*, although the definitions are similar. Instead we use the presence of mud/sandflats to indicate occurrence of other targeted habitats such as *1310 Salicornia seashores.*

Accumulated salt and saltpans on shores of coastal meadows are registered as they indicate occurrence of targeted *1310 Salicornia seashores, 1330 Atlantic coastal meadows* and *1630 Baltic coastal meadows*. Saltpans occur on both west and east coasts of Sweden and forms in depressions on gently sloping shores where water gathers and are later dried out. They can be identified by the interpreter as dark to whitish depressions that are more or less devoid of vegetation due to the high salinity at the location (Fig. 18 B). The assessment area for saltpans is within the 20 meter wide transect area.

Lagoons are expanses of coastal water with varying salinity and water volume that are wholly or partially separated from the sea by sand banks, rocks or vegetation that limits the water exchange with the sea. It is a very diverse nature type with a water depth that normally does not exceed 4 meters. Interpreters in the seashore inventory have classified presence of lagoons when line segments intersect the shores of a lagoon (Fig. 18 C).

4.2.7 Exposure and exploitation

Wave exposure and anthropogenic exploitation was also considered during interpretation. Exposure was estimated through an appraisal of SEPA's exposure data. When the interpreter estimates this data to be incorrect (by at least two classes), a new class is registered. This generally applied to cases where our intersection points and assessment area worked at higher resolution compared with the more generalized (coarse) SAKU coastal exposure model (Table 9). The degree of exposure was not used in the process of selecting field points for phase two.

***Table 9**: Exposure classes used in photo interpretation of MOTH Seashore inventory. Exposure code 1-8 and 99 is based on SEPA exposure classification system (Wennberg, 2006 (SAKU)) that in turn based their classification on European Nature Information System (EUNIS). Code 0 was added for the purpose of this inventory to indicate where interpreter accepts the SAKU classification. For further information see Appendix 3 in Wennberg, 2006.*

Exposure code	Exposure class	Explanation	Water depth (m)
0	OK	Photo interpreter accepts SAKU class	
1	land	Land	
2	ultra sheltered	Shallow sheltered bays	0 - 1
3	extremely sheltered	Shallow sheltered bays	0 - 1
4	very sheltered	Sheltered estuaries	1 - 3
5	Sheltered	Sheltered estuaries	3 – 6
6	mod exposed	Other areas	6 - 10
7	Exposed	Other areas	>10
8	very exposed	Other areas	6-200m
99	unclassified sea	Other areas	

Much of the Swedish coastline has been subject to exploitation of some sort and this needed to be considered during the survey. We define exploitation as an *anthropogenic physical modification of the natural environment* (Mattisson, 2003). Various types of exploitation is registered by the interpreter when noted closer to sampling point and transect than what is shown on property map or jetty registry (Table 10). This data was later used together with data from property map and jetty registry during the selection process to define presence of exploitation for a particular intersection point and transect. The intersection point's proximity to an exploitation indicator specifies whether it is exploited or non-exploited by creating a buffer around the indicator. This data was used during the process of selecting field points for phase two.

***Table 10:** Illustrates the exploitation categories that were considered by photo interpreters and how these were registered as well as which data sources were used for comparison with the CIR image.*

Exploitation category	Point/line	Data source / comparison
jetty	point	jetty registry
house	point	property map
dumping ground	point	
road	line	property map
dredging	line	
constructed/paved	line	property map
other	point/line	

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6 Appendices:

Appendix 1: Variables noted for special occurrences during Terrestrial Habitat Inventory

Note	**Explanation**	**MMU**
Small island or islet (**IS**)	This note is used in cases when the point falls on a smaller island or islet that is generalized to the surrounding water (1000 or 3000) because it is smaller than the minimum mapping unit	< 0.1 ha
Sea-shore note (**N_S**)	Note 1210, 1610 and 1620 when these co-occur with other habitat types. This note can be registered with all habitat types when they co-occur with one of the mentioned sea-shore types. This is why the application of the note is not indicated later in the key. It is probable that the co-occurrence is most common amongst sea-shore habitats, but it is also possible in cases such as forest habitat types and for example 1610 Baltic Esker Island	
Small snowbed (**N_SS**)	Small snowbeds are generalized to the surrounding habitat type and is given note N_SS. **801** SS snowcover **802** SS substrate dominated **803** SS moss dominated **804** SS moss-dwarf shrub-graminoid **805** SS graminoid- dwarf shrub -herb **809** SS vegetation type unsure	0.01- 0.1 ha
Medium sized snowbed (**N_SM**)	Medium sized snowbeds are given suitable habitat class, and the note S_SM to indicate it is a snowbed **811** SM snowcover -> 9998 **812** SM substrate dominated -> 8900 **813** SM moss dominated -> 8900 **814** SM moss-dwarf shrub-graminoid -> 4860 **815** SM graminoid- dwarf shrub -herb -> 6815/4860/7140 **819** SM vegetation type unsure -	0.1 – 2 ha
Lage snowbed (**N_SL**)	Large snowbeds are given suitable habitat class, and the note N_SL, to indicate it is a snowbed **821** SL snowcover -> 9998 **822** SL substrate dominated -> 8900 **823** SL moss dominated -> 8900 **824** SL moss-dwarf shrub-graminoid -> 4860 **825** SL graminoid- dwarf shrub -herb -> 6815/4860/7140 **829** SL vegetation type unsure –	> 2 ha

Note Aapamire (**N_Aa**)	It is recommended that the interpreter overviews the area in order to decide whether the grid point fall in a mire that is part of a larger complex (>10 ha) and comprises parts (> 0.1 ha) that can be classified Transitional mires 7143. All points that fall into such complex should be classified into the normal mire classes, but also noting that they are part of a complex by assigning note 7310 Aapamire	> 10 ha
Note for AI Non-annex 1 classifications; ***6999*** *Other open non-annex 1 habitat*, ***7900*** *Non-annex 1 mire*, ***9998*** *Interpretation not possible*	For these three non-annex 1 AI codes, type is always noted, according to the list below. For 6999 the following notes are used: 1 Parking area 3 Parkland 4 Quarry 5 Shooting range 6 Powerline corridor 7 Football field 8 Golf course 11 Road 13 Railway 14 Airport 15 Other altered land 16 Industrial areas 17 Recreational area For 7900 the following notes are used: 718 Peat extraction area 719 Ditched mire 720 Degenerated raised bog For 9998 the following notes are used: 930 Shadow 931 Cloud 932 Cloud shadow 933 Snow cover	0.1 ha

Appendix 2: List of AI classes used in Terrestrial Habitat Inventory

Aerial photo interpretation (AI) classes used during 2010-2013, the AI-class type. Nomenclature as far as possible follows the habitat manual by Gardfjell & Hagner, 2013 and in cases where AI classes have changed, results have been pooled and the latest 2013 name is used.

* note for Aapamire, **excluded (for various reasons) in later seasons.

English name	AI-class type	Code_orig	2010	2011	2012	2013	Code_new
Marine water	η	1000	1	1	1	1	1000
Drift lines	α	1210	1	1	1	1	1210
Boulder- gravel dominated banks	α	1220	1	1	1	1	1220
Sea cliffs	α	1230	1	1	1	1	1230
Cliff seashore	α	1239	0	0	0	1	1239
Atlantic coastal meadows	α	1330	1	1	1	1	1330
Baltic esker islands	α	1610	1	1	1	1	1610
Baltc islets	α	1620	1	1	1	1	1620
Baltic coasatal meadows	α	1630	1	1	1	1	1630
Sandy shores	α	1640	1	1	1	1	1640
Collective code for boulder, gravel and sandy seashores	δ	1820	1	1	1	1	1820
Marine shore dominated by substrate (sand, gravel, boulder) (non-annex habitat 1)	ζ	1950	1	1	1	1	1950
Boulder or gravel on land upheaval coast	ε	1952	1	0	0	1	1952
Marine shore dominated by tall grass, sedges, rushes (non-annex 1 habitat)	ε	1955	0	1	0	0	1995
Marine shore dominated by tall grass, sedges, rushes (non-annex 1 habitat)	ε	1995	0	0	1	1	1995
Coastal wooded sanddunes	α	2180	1	1	1	1	2180
Humid dune-slacks	α	2190	1	1	1	1	2190
Inland dry sand heaths with dwarf shrubs	α	2320	1	1	1	1	2320
Inland grass dominated sanddunes	α	2330	1	1	1	1	2330
Collective code for coastal open sanddunes	β	2800	1	1	1	1	2800
Collective code for inland open sanddunes	β	2810	1	1	1	1	2810
Limnic water	η	3000	1	1	1	1	3000
Fennoscandian natural rivers	α	3210	1	1	1	1	3210
Alpine rivers and the herbaceaous vegetation along their banks	α	3220	1	1	0	0	3860
Collective code for alpine rivers - pooled with 3860	β	3840	1	0	0	0	3860
Collective code for alpine rivers (incl. former 3840)	δ	3860	0	0	1	1	3860
Limnic shore dominated by substrate (sand, gravel, boulder) (non-annex habitat 1)	ε	3950	0	1	1	1	3950
Limnic (non-annex 1 habitat) shore dominated by tall grass, sedges, rushes (changed to 3995)	ε	3955	0	1	0	0	3995
Other (non-annex 1) alpine rivers (part of collective code 3860)	ε	3960	1	1	0	0	3860
Limnic (non-annex 1 habitat) shore dominated by tall grass, sedges, rushes	ε	3995	0	0	1	1	3995
Non-annex 1 rivers	ε	3999	1	1	1	1	3999
European dry heaths	α	4030	0	1	1	1	4030
Alpine and boreal heaths	α	4060	1	1	1	1	4060

English name	AI-class type	Code_orig	2010	2011	2012	2013	Code_new
Sub-Arctic Salix spp	α	4080	1	1	1	1	4080
Collective code for wet grassland, heath and mire	γ	4830	1	1	1	1	4830
Collective code for sub-alpine salix scrub, tall herb com., wet grassland, heath and mire	γ	4850	1	1	1	1	4850
Collective code for alpine wet heath and mire	γ	4860	1	1	1	1	4860
Collective code for alpine rivers and wet grassland	γ	4870	1	0	0	0	4870
Collective code for sub-alpine salix scrub, and tall herb communities	γ	4880	1	1	1	1	4880
Juniperus communis formations below the tree line	β	5130	1	1	1	1	5130
Juniperus communis formations on dry heaths below tree line	α	5131	0	1	1	1	5131
Juniperus communis formations on calcareous grasslands	α	5132	0	1	1	1	5132
Basophilic grassland comminity on calcarerous bedrock	α	6110	0	1	1	1	6110
Nordic alvar	α	6280	1	1	1	1	6280
Wet grassland	α	6410	0	1	1	1	6410
Tall herb communities	α	6430	1	1	1	1	6430
Alluvial meadows	α	6450	1	1	1	1	6450
Mountain hay meadows	α	6520	1	1	1	1	6520
Collective code for dry- mesic grassland and heath	β	6810	1	1	1	1	6810
Collective code for alpine grassland (calcarerous and siliceous)	β	6815	1	1	1	1	6815
Collective code for wet grassland and heaths	β	6820	1	1	1	1	6820
Collective code for alpine heaths and grasslands	γ	6825	1	1	1	1	6825
Collective code for tall herb community and alluvial meadows	β	6830	1	1	1	1	6830
Collective code for dry to wet grassland, heath and mire below tree line	γ	6835	1	1	1	1	6835
Collective code for coastal meadows and cultivated/managed grassland	δ	6840	1	1	1	1	6840
Collective code for natural, semi-natural and cultivated grassland	δ	6845	1	1	1	1	6845
Collective code for wooded pastures and meadows, wooded cultivated pastures, shrub-dominated pasture and non-annex 1 forest	δ	6850	1	1	1	1	6850
Open cultivated grassland	ε	6910	1	1	1	1	6910
Open cultivated pasture	ε	6911	1	1	1	1	6911
Wooded cultivated pasture	ε	6913	1	1	1	1	6913
Shrubrich(pastures)	ε	6916	1	0	0	0	6916**
Built-up areas	ζ	6920	1	1	1	1	6920

English name	AI-class type	Code_orig	2010	2011	2012	2013	Code_new
Arable land	ζ	6930	1	1	1	1	6930
Shrub-dominated land	ζ	6997	0	1	1	1	6997
Other open non-annex 1 habitat (type noted)	ζ	6999	0	1	1	1	6999
Collective code for open mires (uncertain specific type)	η	7000	0	1	1	1	7000
Active raised bogs	α	7110	1	1	1	1	7110
Blanket bogs	α	7130	1	1	1	1	7130
Open mires	α	7140	1	1	1	1	7140
Transitional mires	α	7143	0	1	1	1	7143
Spring	α	7161	0	1	1	1	7161
Springfens	α	7162	1	1	1	1	7162
Calcareous fens with Cladium mariscus (and species of the *Caricion davallianae*)	α	7210	1	1	1	1	7210
Petrifying springs with tufa formation	α	7220	0	1	1	1	7220
Alcaline fens	α	7230	1	1	1	1	7230
Mineral-rich spring in alcaline fen	α	7234	0	1	1	1	7234
Springfen in aapamire	α	7295	1	0	0	0	7162*
Alcaline fen in aapamire	α	7296	1	0	0	0	7230*
Open mire in aapamire	α	7298	1	0	0	0	7140*
Aapamire	α	7310	1	0	0	0	7143*
Spring in aapamire	α	7312	1	0	0	0	7161*
Mire woodland in aapamire	α	7318	1	0	0	0	9740*
Collective code for open mire in Aapamire	β	7319	1	0	0	0	7000*
Palsa mires	α	7320	1	1	1	1	7320
Collective code for springs	β	7810	1	1	1	1	7810
Collective code for raised bog and open mire	β	7815	1	1	1	1	7815
Collective code for open mire, alcaline fen and springfen	β	7820	1	1	1	1	7820
Collective code for open mires (uncertain specific type)	β	7830	1	0	0	0	7000
Collective code for open mire, alcaline fen and springfen in aapamire	β	7840	1	0	0	0	7820*
Collective code for mire woodland, and open mire in aapapire	β	7841	1	0	0	0	7841
Collective code for mire woodland and swamp woodland in aapamire	γ	7842	1	0	0	0	9842*
Collective code for moist forest close to aapamire	γ	7844	1	0	0	0	9845*
Non-annex 1 mire (disturbed)	ζ	7900	1	1	1	1	7900
Vegetated siliceous bedrock	α	8230	1	1	1	1	8230
Limestone pavements	α	8240	0	1	1	1	8240
Permanent glaciers	α	8340	1	1	1	1	8340
Collective code for siliceous and calcareous scree	β	8810	1	1	1	1	8810
Collective code for siliceous and calcareous rocky slopes	β	8820	1	1	1	1	8820

English name	AI-class type	Code_orig	2010	2011	2012	2013	Code_new
Collective code for calcareous thin soils and flatrock	β	8830	1	1	1	1	8830
Collective code for siliceous and calcareous bedrock	β	8840	1	1	1	1	8840
Non-annex 1 open substrate-dominated land	ζ	8900	1	1	1	1	8900
Western taiga natural disturbance	α	9009	1	1	1	1	9009
Western taiga	α	9010	1	1	1	1	9010
Primary successional forest of landupheaval coast	α	9030	1	1	1	1	9030
Nordic subalpine birch forest	α	9040	1	1	1	1	9040
Herb-rich Picea abies dominated forests	α	9050	1	1	1	1	9050
Coniferous forest on glaciofluvial Eskers	α	9060	1	1	1	1	9060
Wooded pastures	α	9070	1	1	1	1	9070
Deciduous swamp woods	α	9080	1	1	1	1	9080
Broadleaved hardwood forest in slopes, screes and ravines	α	9180	1	1	1	1	9180
Mire woodland	α	9740	1	1	1	1	9740
Alluvial forest	α	9750	0	1	1	1	9750
Alluvial broadleaved hardwood dominated forest	α	9760	0	1	1	1	9760
Collective code western taiga and broadleaved hardwood forest	β	9801	1	1	1	1	9801
Collective code western taiga and non-annex 1 forest	δ	9810	1	1	1	1	9810
Collective code for broadleaved hardwood forests	β	9820	1	1	1	1	9820
Collective code for herb-rich coniferous forest and taiga	β	9830	1	1	1	1	9830
Collective code for alluvial forests	β	9840	1	1	1	1	9840
Collective code for mire woodland and raised bog	β	9841	1	1	1	1	9841
Collective code for mire woodland, swamp woodland and alluvial forest	γ	9842	1	1	1	1	9842
Collective code for mire woodland and western taiga	γ	9843	1	1	1	1	9843
Collective code for mire woodland, wooded springs and springfens	β	9844	1	1	1	1	9844
Collective code for swamp, alluvial and other wet forest	β	9845	1	1	1	1	9845
Collective code for wooded mire, wooded alcaline fens with and without *Cladium mariscus*, petrifying springs with tufa formation	β	9846	0	1	1	1	9846
Collective code for montane birch forest, wooded taiga rich in deciduous trees and herb-rich conferous forest	β	9849	0	1	1	1	9849
Non-annex 1 forest	ζ	9900	1	1	1	1	9900
Forest on formerly arable or open vegetated land	ε	9910	0	1	0	0	9910
Wooded inland dunes	ε	9915	1	1	1	1	9915
Marine shore dominated by substrate (sand, gravel, boulder) (non-annex habitat 1)	ε	9950	1	0	0	0	1950
Managed broadleaved hardwood forest	ε	9991	1	1	1	1	9991

English name	AI-class type	Code_orig	2010	2011	2012	2013	Code_new
Interpretation not possible (reason noted)	ζ	9998	1	1	1	1	9998
Non-annex 1 habitat (reason noted)	ζ	9999	1	0	0	0	6999

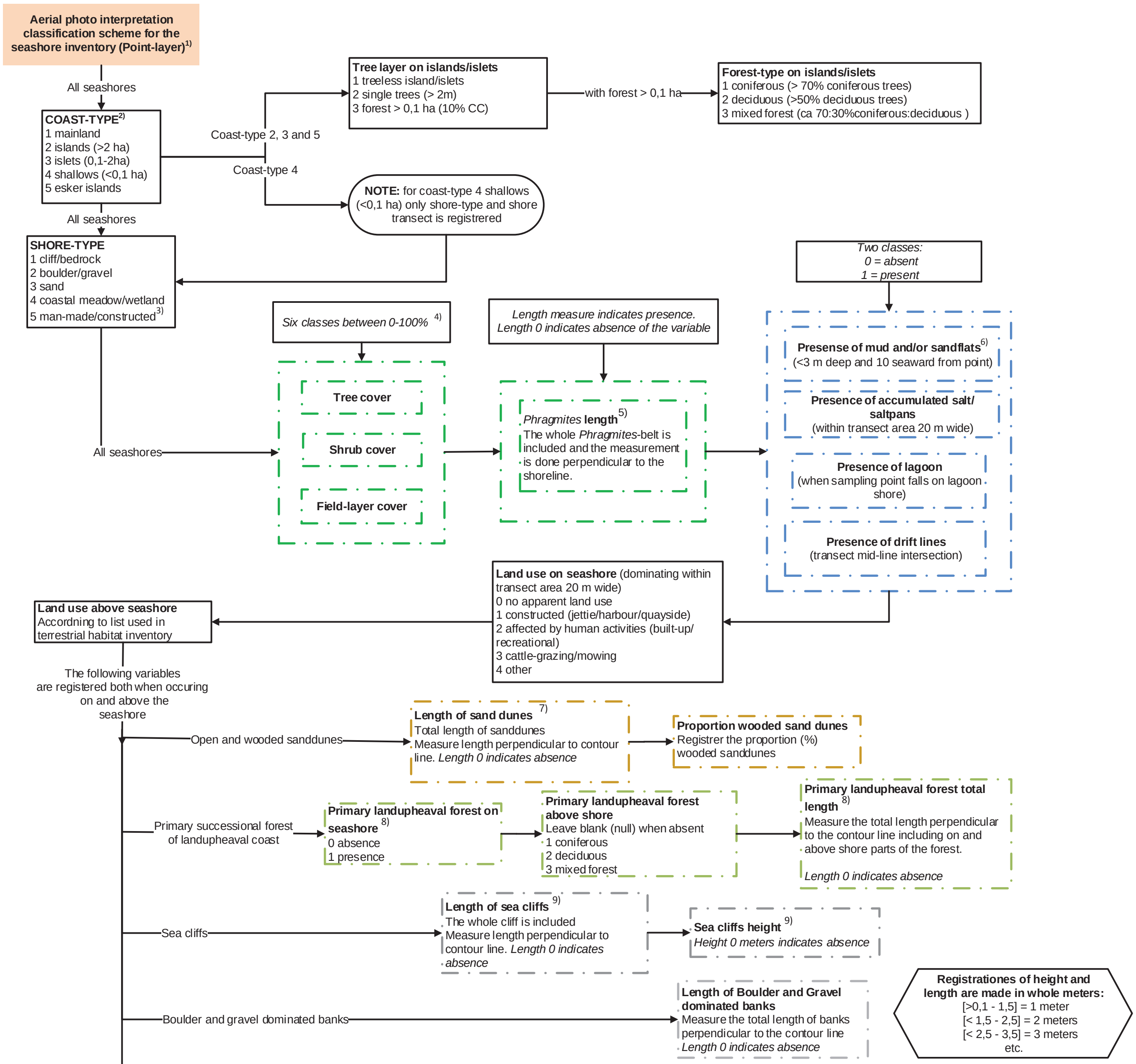
Appendix 3: Seashore Inventory Table of Variables

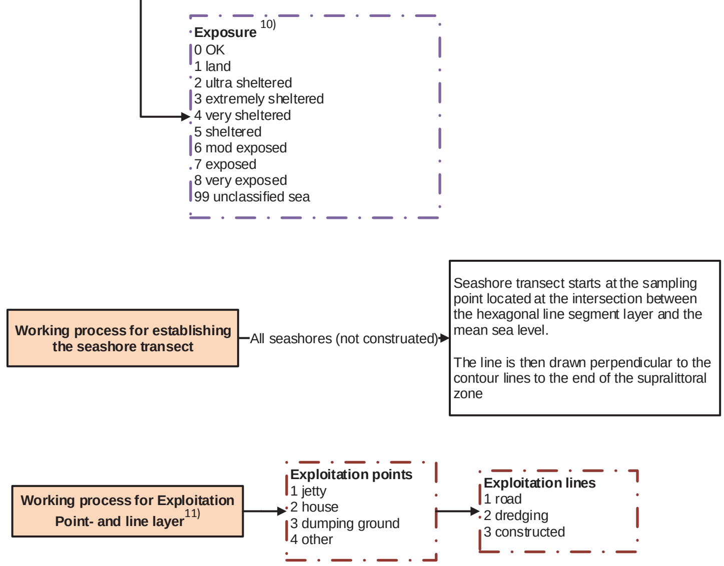
VARIABLE	CLASSES	ASSESSMENT AREA	SUBCLASSES	ASSESSMENT AREA
Coast type	mainland	transect and point		
	island (>2 ha)			
	islet (0,1-2 ha)			
	shallow (<0,1 ha)			
	esker island			
Shore type	cliff	at sampling point		
	boulder/gravel			
	sand			
	coastal meadow/wetland			
	constructed/man-made			
Tree layer	treeless island/islet	on islands and islets	coniferous forest (>70% coniferous spp)	on island/islet with forest (>0,1 ha, 10% CC)
	single trees		deciduous forest (> 50% deciduous spp)	
	forest (>0,1 ha, 10% CC)		mixed forest (approx. 30 % deciduous spp)	
Land use on seashore	no apparent land use	dominating within shore transect		
	constructed/man-made			
	affected (residential/recreational)			
	grazing/mowing			
	other			
Land use above seashore	see separate table x for classes	dominating within 0,1 ha immediately above shore transect		
Crown cover trees	6 classes from 0 -100% cover	within shore transect		
Cover shrubs	6 classes from 0 -100% cover	within shore transect		
Cover field layer	6 classes from 0 -100% cover	within shore transect		
Phragmites	length in meters along transect line measured both above and below mean water level	length of Phragmites belt along transect line		
	0 meters when absent			
Presence/absence of mud- and sandflats	1 when present			
	0 when absent			
Presence/absence of saltpans (accumulated salt)	1 when present			
	0 when absent			
Presence/absence of drift lines	1 when present			

VARIABLE	CLASSES	ASSESSMENT AREA	SUBCLASSES	ASSESSMENT AREA
	0 when absent			
Presence/absence of coastal lagoons	1 when present			
	0 when absent			
Sand dunes	length in meters when present, 0 meters when absent	usually above transect, measured perpendicular to the contour line		
Proportion wooded sand dunes	estimate the proportion (%) of dune length that are wooded, 0 when absent	beyond transect, measured perpendicular to the contour line		
Presence/absence of land upheaval forest on shore	1 when present	can occur both on the seashore (within the transect) and above the seashore (beyond transect line)		
	0 when absent			
Type of land upheaval forest above the shore	coniferous	above the shore (beyond transect line)		
	deciduous			
	mixed forest			
Length of land upheaval forest	total length in meters of land upheaval forest (0 when absent)	both on the seashore (within the transect) and above the seashore (beyond transect line)		
Sea cliffs	when present measure the length of the cliff	both on and above the transect, perpendicular to the contour line		
	when present measure height of the cliff	from bottom to the highest point of the cliff		
Gravel and boulder dominated banks	when present measure the length of the banks	usually beyond transect, measured perpendicular to the contour line		
Exposure	OK	at sampling point		
	land			
	ultra sheltered			
	extremely sheltered			
	very sheltered			
	sheltered			
	mod exposed			
	exposed			
	very exposed			
	unclassified sea			
Exploitation		registered when exploitation is noted closer to the sampling point/transect than what can be seen in property map or jetty registry		
	jetty			
	house			
	dumping ground			

VARIABLE	CLASSES	ASSESSMENT AREA	SUBCLASSES	ASSESSMENT AREA
	road			
	dredging			
	constructed/paved			
	other			

Appendix 4: Seashore Inventory Classification Scheme





1) The sampling point is placed where the line segment (hexagon layer) intersects the shoreline at mean sea level

2) The coastline of large islands Gotland and Öland are given coast-type mainland.

3) The shoretype constructed/man-made is given shore-length 0 and no transect is drawn.

4) Coverage of vegetation classes are performed on 10 meters each side of the transect resulting in a total assessment width of 20 meters (length will vary between different seashores)

5) The whole *Phragmites*-belt is included and is measured perpendicular to the shoreline. In cases when *Phragmites* grows in tuft-wise manner (and not in a clear belt) make an estimate of the length the tufts added together.

6) The classification of mud and/or sand flats does not include pure sandy bottoms or sand reef.

7) Open and wooded coastal sand dunes. Sand dune length is measured perpendicular to the contour line and all dune habitat types are included in the measurement, except embryonic shifting dunes, which are included in the sandy shores.

8) Land upheaval forest. The forest occurs on and above the seashore up to 3 m above sea level and includes the entirety of the *Salix* shrub border, measured perpendicular to the contour line

9) Sea cliffs have < 10% CC. Both height (above sea level) and length (from cliff base to top) are measured within the area described in the definition. The criteria related to cliff slope in the habitat definition is ignored for the purpose of this survey, which means the cliff only have to meet conditions of height and length.

10) During this survey an appraisal of SAKU's exposure data is made and in cases where the interpreter estimates this data to be incorrect, a new class is registered. There need to be a discrepancy of at least two classes between the interpreters estimate and SAKU's data for a correction to be made in the database.

11) Points and lines are digitalised to indicate exploitation when new structures have appeared (in proximity to the sampling point) that are not indicated on the property map or the registry of jetties. The assessment area includes 100 meters in all directions from the sampling point.