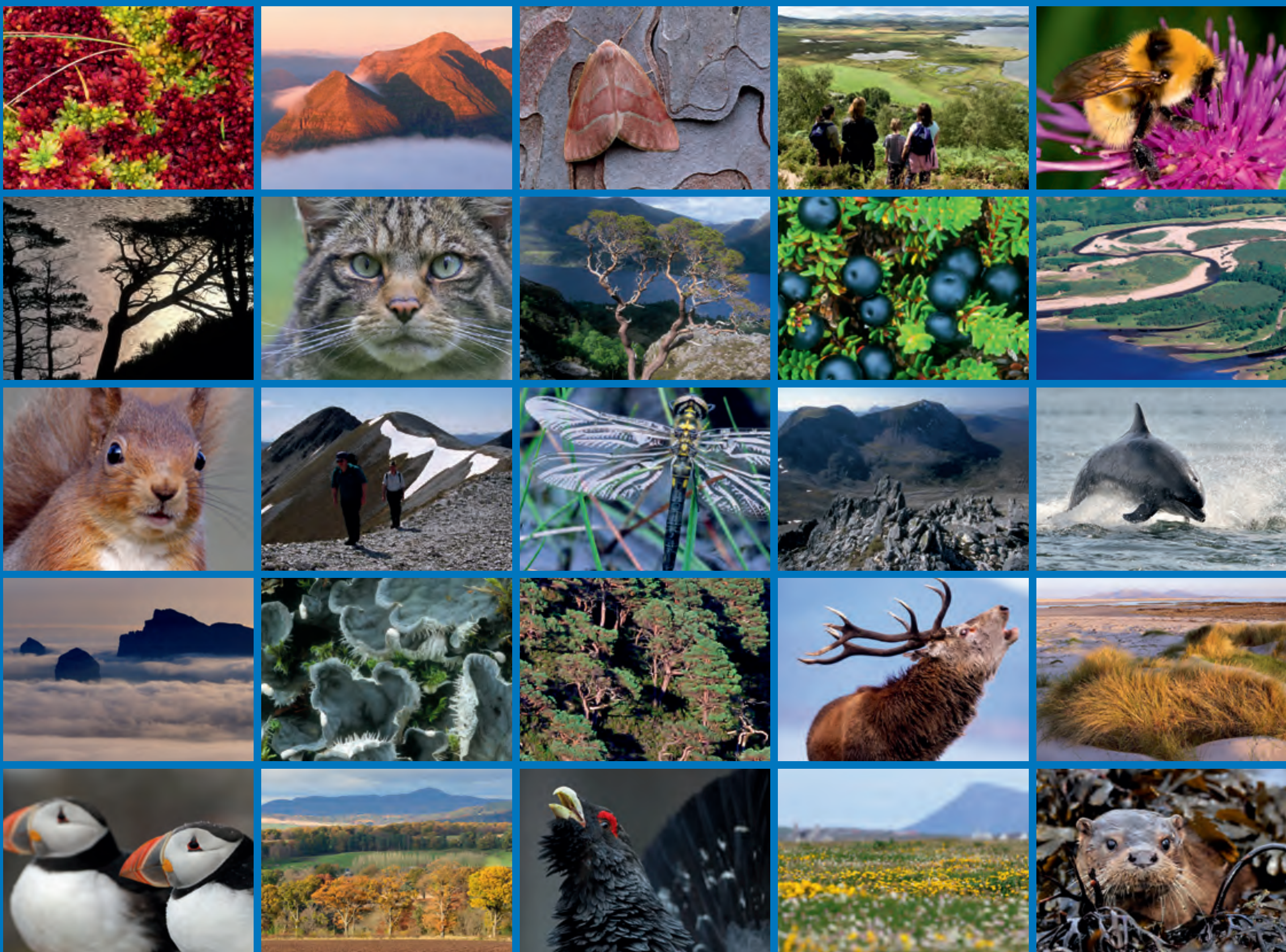
Scottish Natural Heritage
Commissioned Report No. 767

Trial mapping of upland Annex I and EUNIS habitats using stereo colour near-infrared aerial imagery



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COMMISSIONED REPORT

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Trial mapping of upland Annex I and EUNIS habitats using stereo colour near-infrared aerial imagery

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COMMISSIONED REPORT

Summary

Trial mapping of upland Annex I and EUNIS habitats using stereo colour near-infrared aerial imagery

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Keywords

Habitat mapping; habitat classification; upland; colour near-infrared (CIR) aerial imagery; stereo aerial imagery interpretation; upland Annex I habitats; EUNIS; method development.

Background

SNH aims to produce a Habitat Map of Scotland according to the EC Habitats Directive Annex I and EUNIS classifications. This trial investigated the use of false colour infrared (CIR) stereo aerial imagery interpretation with supporting field work as a method for mapping unsurveyed upland areas. This method that has been successfully used in Sweden but it is new to the UK. The report sets out the CIR stereo method used in a 5 km^2 area of Glenfeshie in 2014, and discusses the potential value and issues that the method offers.

Main findings

- There is considerable potential for mapping the habitats targeted in this trial using stereo aerial imagery.
- A full-scale pilot study to develop methods and clarify technical requirements, using an operational team with knowledge and expertise in upland habitats, GIS, and remote sensing techniques is recommended.
- Automated aerial imagery segmentation should be explored further.
- An upland mapping manual will require reliable interpretation indicators and clear mapping rules.
- A 'toolbox' approach incorporating this method is recommended for upland mapping.

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1. INTRODUCTION

Scottish Natural Heritage (SNH) is committed to producing a Scotland-wide habitat map (the Habitat Map of Scotland, HabMoS) using the EC Habitats Directive Annex I and EUNIS classifications. This map will be built from existing data as well as new habitat surveys. In 2013 SNH held a series of workshops to determine how to map unsurveyed upland areas for this map. The workshops resulted in a proposal to pilot a method using false colour infrared (CIR) stereo aerial imagery interpretation with supporting field work.This is a method that has been successfully used in Sweden but it is new to the UK. Due to financial constraints, the pilot proposal did not go ahead. Instead this smaller trial, undertaken by SNH staff in 2014, has assessed the opportunities that the method may provide in mapping for the HabMoS project. The trial reported here was therefore an initial investigation into a possible way of mapping the upland areas of Scotland where no habitat mapping suitable for incorporation into HabMoS currently exists.

It should be noted that this report describes part of the exploration and development of a work in progress rather than a finished method or project. It therefore includes some detail of decision-making processes, and some of the results include more discussion of methods used and lessons learned about the application of these methods than is usual. This is to provide the context that allows the decision-making processes and the nature of the results to be best understood, and reflects the exploratory nature of the study.

1.1 Purpose

This study aimed to test whether a colour infrared (CIR) stereo aerial imagery interpretation approach had potential to provide SNH with a method to be rolled out across all unsurveyed upland habitats, on its own or in combination with other methods.

Specifically, the purpose was to identify:

- which EUNIS habitats within the study area can be identified and which cannot;
- which Habitats Directive Annex I habitats within the study area can be identified and which cannot;
- whether this approach to mapping Scottish upland habitats should be investigated further.

1.2 Outputs

1. Dataset - Annex I and EUNIS coded habitat polygons for the study area;

2. This report, which:
    a. describes the study methods (with examples of interpretation keys and mapping rules);
    b. informs a decision on whether this method could or should be piloted at a larger scale;
    c. provides a basis for potential further method development.

1.3 Important limitations of this study

This study was a smaller version of a proposal for a wider pilot study for the Habitat Map of Scotland (HabMoS) using CIR stereo imagery and fieldwork. As such it has not addressed all the questions the original pilot was intended to answer. This is due to limited resources, with one person carrying out most of the stereo interpretation (with no one to compare results with), and due to the smaller size of the trial area. For example, this study has not been able to:

- test whether this method is repeatable;
- test how fast this method is (i.e. how long it would take and how much it would cost);
- fully test how accurate the interpretation of different habitats is;
- try to identify all habitats and their inherent variation as not all exist in the trial area;
- provide a full mapping manual with mapping rules (for minimum mappable units (MMU), mosaics etc) and interpretation keys for all habitats encountered.

2. METHODS

2.1 Mapping strategy

Mapping habitats using stereo CIR aerial imagery together with targeted field work is straightforward and consists of a feedback loop involving interpretation and field checks. An outline of the mapping strategy is found in Figure 1 below. The different stages are described in brief.

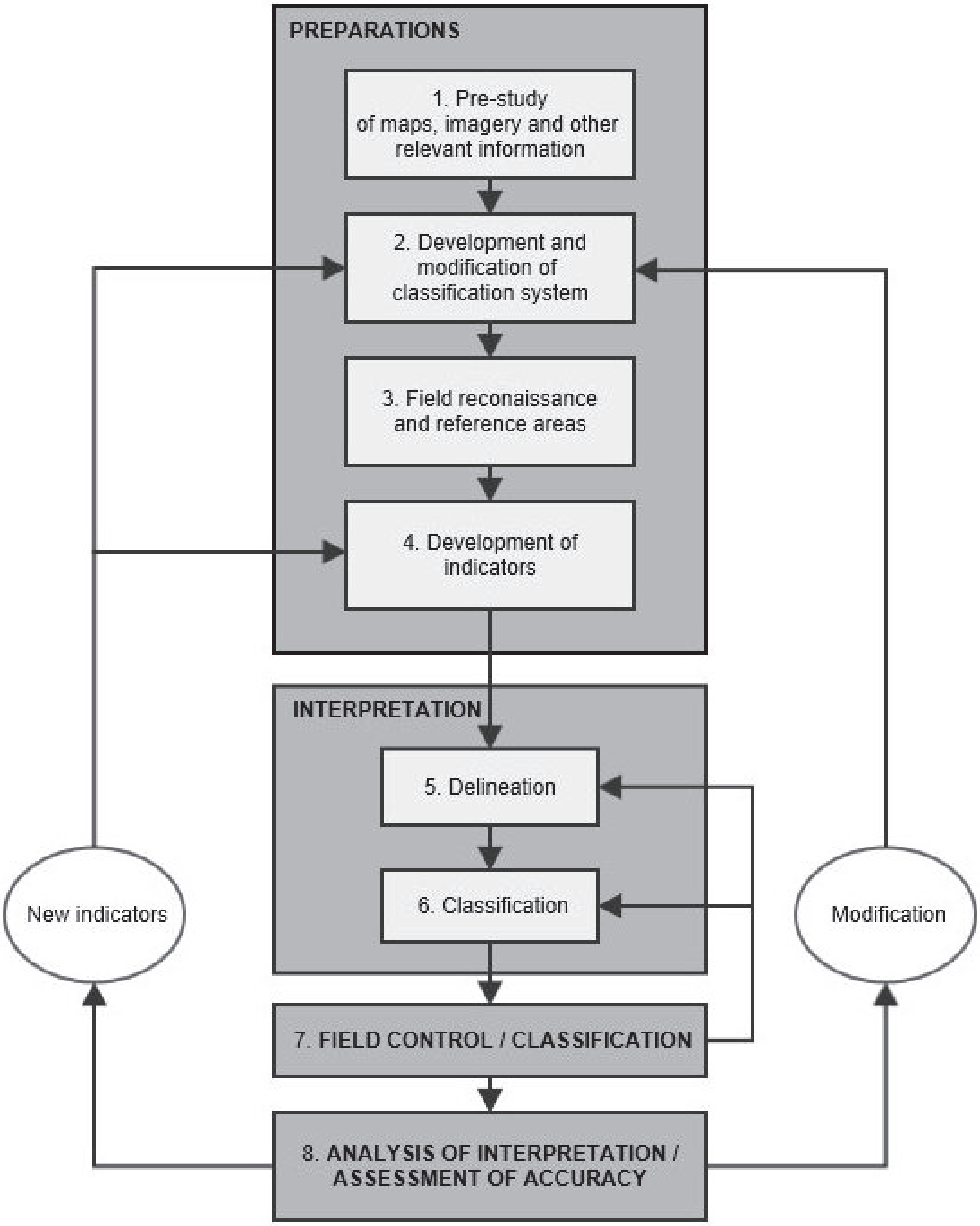


Figure 1. Model for CIR imagery interpretation and indicator development. Modified from Ihse (2007).

The methodology is based on work by Ihse (2007) and further developments within the Natura 2000 inventory (Skånes *et al*., 2007 and Skånes and Andersson, 2011) and the National Inventory of Landcapes in Sweden (Allard, 2012).

1. *Pre-study*

   This stage involves study of the imagery, familiarisation with the area's history and ecology, and collection of information to support the interpretation such as:

   - Historical maps;
   - Geological maps (soil, bedrock etc.);
   - Previous surveys;
   - Any other datasets or data analyses that can aid the interpretation.

2. *Development and modification of classification system*

   Where there is flexibility, necessary adjustments are made to definitions of habitat classes so that they are practically identifiable in imagery as well as in the field.

3. *Field reconnaissance and reference areas*

   Connection is made between the habitats in the field and their representation in the imagery studied in Step 1.

   In the field, reference areas for each of the habitats to be mapped in the following steps are identified.

4. *Development of indicators*

   Based on the field reconnaissance, interpretation indicators are selected and described. The aim is to produce a set of indicators that together help separate the different habitats in the classification system. Some indicators will occur in different habitats but the combination of indicators should be unique and only point to one habitat. If the habitat differs in appearance between e.g. biogeographical regions or due to seasonality of the imagery, this also needs to be taken into account.

   Depending on how they are aggregated, there are around eight different indicator groups:

   1. Colour / Tone
   2. Physiognomy (structure, layering, height, density, cover, texture)
   3. Shape
   4. Size
   5. Pattern (regular – irregular)
   6. Site conditions (climate, soil properties, moisture regime, topography, nutrients, exposure)
   7. Landscape context (location, altitude, surrounding habitats, land use etc.)
   8. Management and manmade structures (current as well as past)

   An indicator set should ideally contain as few indicators as possible but still point to one habitat and one habitat alone.

   If two habitats have exactly the same interpretation indicators, they must be aggregated to a higher hierarchical level which can only be separated by fieldwork (see Step 7).

Additional information from other relevant sources can help create search areas for particular habitats which cannot be identified from indicators at this stage. The sources will vary depending on the habitat, but can for example include precipitation data, steepness of slope or soil maps.

5. *Delineation*

   The stereo imagery is interpreted and boundaries are drawn to separate habitats. This begins with the most obvious boundaries, and further more detailed delineations are made in subsequent steps.

6. *Classification*

   The delineated polygons are classified with the help of interpretation indicators established in Step 4. The area is systematically searched several times, the interpreter concentrating on one class at a time, allowing them to use the same references throughout the area.

7. *Field control / Classification*

   - Field controls are applied to targeted sample polygons within each habitat;
   - Field controls are also directed to polygons where the classification is uncertain. If there is a set of polygons that look the same, only a sample of them needs to be visited to finalise the classification;
   - Final classification of habitats that can only be separated in the field is made.

8. *Analysis of interpretation and Accuracy assessment*

   Using the field controls, the map is analysed and an accuracy assessment is made. If the accuracy is poor, further development of indicators and/or a modification of the classification system have to be made using the feedback loop shown in Figure 1.

The application of each of these stages is discussed in Section 3.

2.2 Study area

An area in Glenfeshie in the south-western Cairngorms was chosen for the study (Figure 2). This is a mountainous area supporting a range of upland Annex I habitats including some of the more fragmentary habitats expected to be the most challenging to identify using this method. We used a 1km wide transect from the edge of woodland in the valley at 500m to the high-altitude plateau of Moine Mhor which reaches 953m.

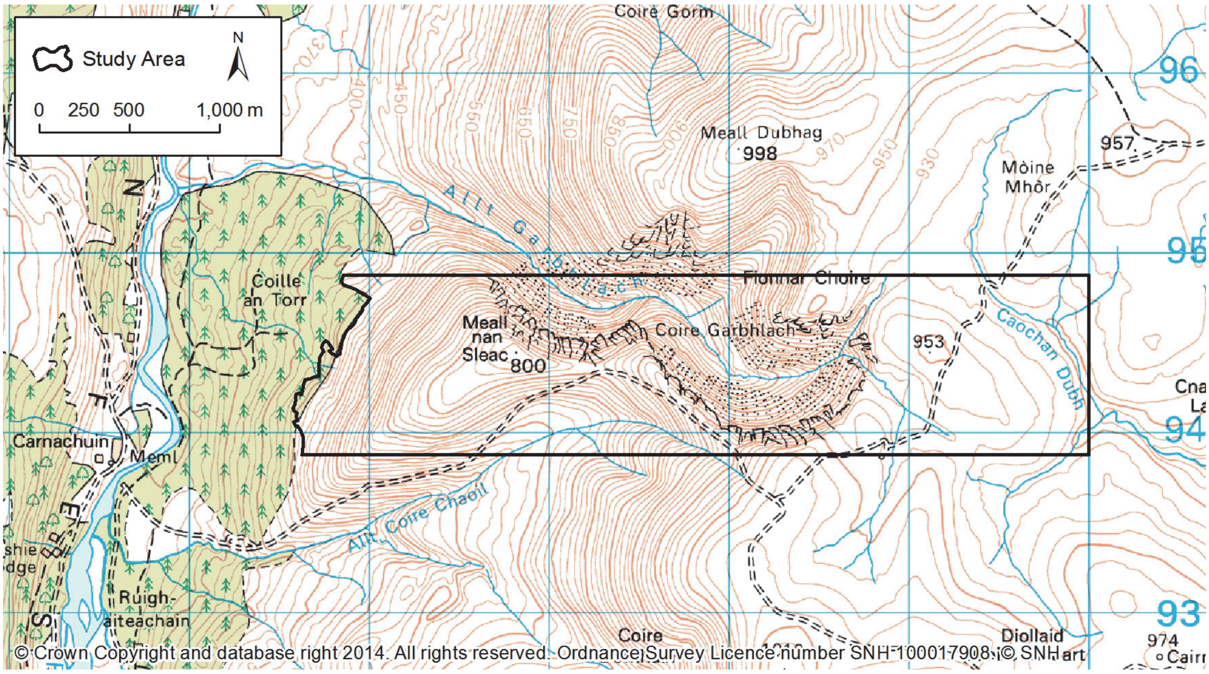


Figure 2. Study area.

2.3 Stereo imagery and orthophotos

Through our current aerial imagery contract, SNH acquired true colour and false colour infrared orthophotos (Getmapping 2013a, 2013b) and stereo frames (Getmapping 2013c) for the mapping trial (Figure 3). The aerial imagery was captured on 19 July 2013 at 25cm resolution by an Ultracam Eagle camera. Block files used to build the stereo models were created by Getmapping using photogrammetric orientation parameters contained within the corresponding AT (aerial triangulation) files.

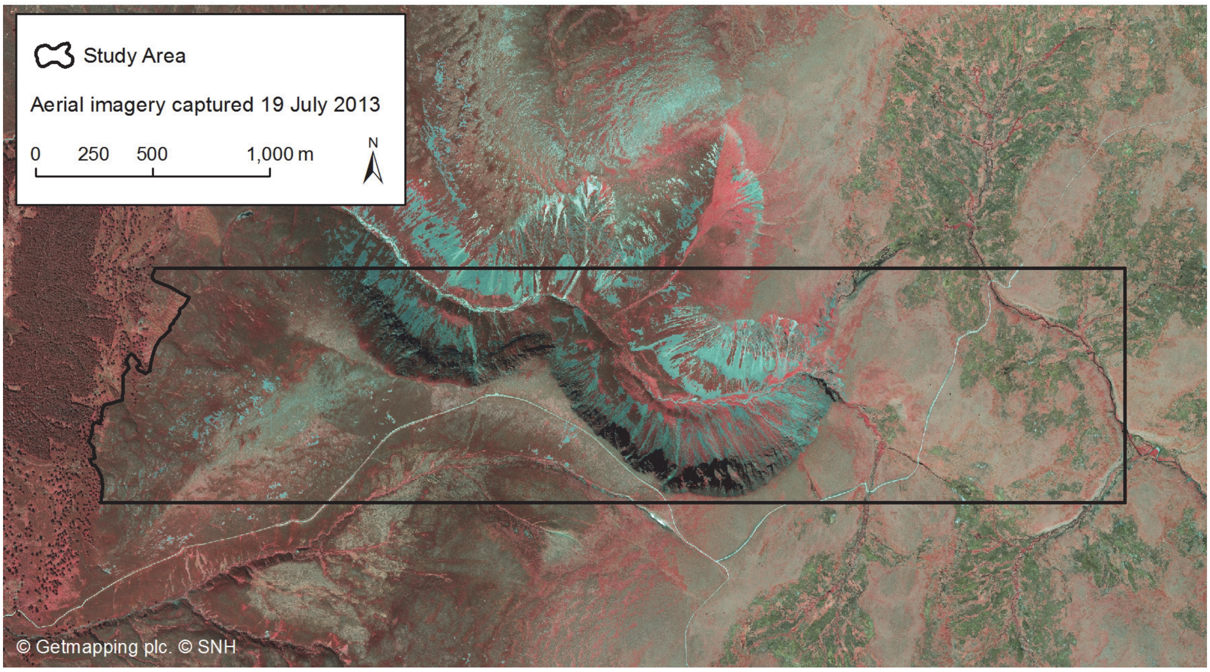


Figure 3. False colour infrared imagery of the study area.

2.4 Software and hardware

A computer work station was specifically configured to run Summit LITE Evolution (DAT/EM) for ArcGIS. This is software developed for advanced aerial imagery interpretation where photogrammetric orientation enables 3D stereo measurements and vector digitising directly into ArcGIS. The feature dataset is created in ArcMap and is then automatically superimposed in the stereo window in Summit LITE when both applications are open.

After the mapping exercise was completed, segmentation of aerial imagery was carried out by Environment Systems Ltd. using eCognition software. This divides the image up into homogeneous regions, so that similar adjacent pixels are grouped together. The objects created are based upon the colour, shape, texture and geographic relationships with the real-world features they describe. Elements of this segmentation were compared with manual polygon delineation.

2.5 Classification systems

Habitats were classified according to the European Nature Information System (EUNIS) developed by the European Environment Agency (EEA). The purpose of EUNIS is to assist in the Annex I process, in the development of indicators and in environmental reporting (European Environment Agency 2015). The EUNIS classification system is largely based on interpretation and grouping of pre-existing, often national, habitat and vegetation classification systems within a European framework. It therefore does not have an independent supporting body of detailed habitat descriptions and floristic data allowing identification of EUNIS habitats. Such identification thus generally relies on correspondence with other classifications, in the case of GB vegetation the National Vegetation Classification (NVC) (Rodwell 1991-2000). However, EUNIS does not correspond precisely to the NVC, and it also classifies habitats which are not covered in the NVC, such as rock habitats.

European definitions for all EUNIS habitats can be found online in the EUNIS biodiversity database (European Environment Agency, 2015). In the *Manual of Terrestrial EUNIS habitats in Scotland*, Strachan (2015) provides the first formalised Scottish interpretations of the EUNIS habitat definitions. As well as existing EUNIS codes, it sets out several newly created EUNIS habitat codes specific to Scotland, and defines correspondences with key classifications such as Annex 1 and the NVC.

The *Interpretation Manual of European Union Habitats* (European Commission, 2013) sets out the classification of Habitats Directive Annex 1 habitats. Interpretations of the definitions, and descriptions of these habitats as they occur in the UK, are given by the Joint Nature Conservation Committee (JNCC, 2014). A preliminary interpretation of Annex I habitats as they occur in Scotland has been produced (Averis and Averis 2010) but this remains in draft at present. In this project Annex I habitats were identified and labelled using the correspondences in Strachan (2015).

In order to simplify the classification process a list of relevant target habitats which might be encountered in the study was created (Appendix 1). A simplified version displaying the habitat classes actually used is shown in Table 1. Polygons were generally classified according to the dominating habitat, but in some instances, usually where there was a fine-scale mosaic, a secondary habitat was also recorded.

Table 1. Habitat classes used in the Glenfeshie trial, based on EUNIS correspondence table (Strachan, 2015).

EUNIS	EUNIS description	Annex I	Annex I description	NVC Correspondence (* part only)
D1.2	Blanket bogs	H7130	Blanket bog	
D1.22	Montane blanket bogs, *Calluna* and *Eriophorum vaginatum*	H7130	Blanket bog	M1* M2* M3* M15* M19* M20*
D1.24	Wet bare peat and peat haggs on blanket bogs	H7130	Blanket bog	In association with M1* M2* M3* M15* M17 M18* M19* M20* M25*
D2.2C	Soft water spring mires	NONE	NONE	M31-33 M35-36
E4.116	Boreo-alpine [*Deschampsia*]-[*Anthoxanthum*] communities	NONE	NONE	U13a
E4.32€	Siliceous alpine and boreal grasslands	H6150	Siliceous alpine and boreal grasslands	U7 U8 U9 U10 U11 U12 U14
E4.21	Oroboreal [*Carex bigelowii*]-[*Racomitrium*] moss-heaths	H6150	Siliceous alpine and boreal grasslands	U9 U10
E4.32	Oroboreal acidocline grassland	H6150	Siliceous alpine and boreal grasslands	U7 U8
E5.59	Oro-boreal tall-herb communities	H6430	Hydrophilous tall herb fringe communities	U17
F2.1	Subarctic and alpine dwarf willow scrub	Incl. H4080	Incl. Sub-arctic Salix spp. scrub	Includes W20 (H4080)
F2.25	Boreo-alpine and arctic heaths	H4060	Alpine and Boreal heaths	H13 H14 H15 H17 H18* H19 H20 H22 (montane forms of H10,12,16,21 could be assigned here)
F4.2	Dry heaths	H4030	European dry heaths	H7* H8* H9 H10* H12* H16* H18* H21*
H2.31€	Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani*)	H8110	Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani)*	U18* U21* and other non-NVC vegetation
H2	Siliceous and basic screes	H81	Either H8110 or H8120	
H2.4	Temperate-montane calcareous and ultra-basic screes	H8120	Calcareous and calcshist screes	OV38* OV40* other
H3.1#	Siliceous rocky slopes with chasmophytic vegetation	H8220	Siliceous rock slopes with chasmophytic vegetation	other non-NVC
H3.25	Alpine and sub-mediterranean chasmophyte communities	H8210	Calcareous rocky slopes with chasmophytic vegetation	OV39* OV40* and other non-NVC

2.6 Field validation of first draft map by upland habitat experts

Ideally, the interpreters should carry out field validation of the draft map themselves first, in order to refine the interpretation indicators, but due to time constraints and the added value of having habitat experts checking the map, field validation was carried out by NVC expert field surveyors in October 2014. Two independent sets of surveyors (one of two people and one of one person) were used in order to determine whether agreement between the aerial imagery mapping and field validation in relation to delineation and classification might be assessed differently between surveyors.

The field surveyors were given printouts of the infrared imagery overlaid with the delineated and classified polygons. They were also given a field check sheet (Table 2) and point coordinates where they were asked to validate whether the classification of the polygon was 'correct', 'acceptable' or 'not acceptable'. 'Acceptable' was defined as a classification that was not quite what they would have classified the polygon as but not so different as to be misleading. They were also asked to validate the polygon boundary using the same descriptors.

The surveyors were asked to comment on what on-site conditions contribute to the signal in the imagery. This could for example be a specific species, species mix, or an environmental factor such as soil moisture condition. The surveyors were also asked to give any other comments they thought relevant to the mapping.

Table 2. Field check sheet example

Point ID	**Poly ID**	**EUNIS code**	**Dominating EUNIS habitat**	**Secondary EUNIS habitat**	**To check**	**Boundary 1=Correct 2=Acceptable 3=Unacceptable**	**Classification 1=Correct 2=Acceptable 3=Unacceptable**	**Correct class (EUNIS code)**	**Cause of 'signal'**	**Answers / Free comments**
2	27	F4.2	Dry heaths		Polygon classification					

3. RESULTS

3.1 Pre-study (Step 1)

A brief pre-study of the area took account of the following datasets:

Upland Vegetation Survey Project (1989) (Commonly known as 'Black Files'.) converted to National Vegetation Classification (NVC)
British Geological Survey Bedrock 1:50,000K (2014)
British Geological Survey Bedrock 1:10,000K (2014)

The Upland Vegetation Survey was used to select reference areas with a variety of vegetation types.

The geological datasets were studied in order to find information on rock acidity in an attempt to separate calcareous scree and rock habitats from siliceous ones. This information was however not directly evident for a non-geologist. In discussions with Rachel Wignall, SNH Advisory Officer for Earth Science, it was concluded that the British Geological Survey (BGS) datasets need to be interpreted and reclassified by geologists in order to be used to separate calcareous (basic) from siliceous (acidic) rock areas. In discussions between Rachel Wignall and Patricia Bruneau, SNH Advisory Officer for Soils, it was also concluded that James Hutton Institute soil data (variously available in digital and paper form) may be the best source of information to separate habitats of calcareous and siliceous soils. This is because the composition of drift deposits may be significant and BGS drift deposit maps do not contain information on chemical composition. Although some uncertainty would exist, reclassifications for both screes and habitats of calcareous or siliceous soils should be possible but would demand some development work.

3.2 Development and modification of classification system (Step 2)

This project mapped to the EUNIS classification system. Within this trial there was no scope for development or modifications of the existing habitat definitions.

In order to identify Annex I habitats it was necessary to map to the EUNIS level relevant to the Annex I habitat. This resulted in a EUNIS habitat target list (Table 1) ranging from levels 3 to 5 within the EUNIS Classification hierarchy. A few additional classes were included because of other conservation interest as well as to secure a complete classification of the area, as not all habitats fall into Annex 1 types.

Some new EUNIS habitat classes, indicated by # and € symbols, were created to enable Annex I habitats to be fully identified within the classification (Strachan, 2015). This modification of the classification system was made independently of this trial, but some of these classes were required to classify habitats in this trial.

3.3 Field reconnaissance and reference areas (Step 3)

Three areas that were considered to cover most of the habitat variation within the trial site were selected (Figure 4). These were chosen by considering the complexity of aerial imagery signals in combination with the habitats identified by the Upland Vegetation Survey (1989). A section of Coire Garbhlach was included as one of the three areas but due to time constraints the whole corrie had to be excluded from the final mapping exercise. However, the habitats encountered on site in all three reference areas are discussed in the results.

The approach taken with the reference areas was to:

1. Study the aerial imagery

2. Visit the site to make connections between features/habitats and indicators in the imagery
3. Interpret, draw preliminary boundaries and classify polygons based on findings in step 2
4. Re-visit and check boundaries and classification
5. Adjust interpretation, boundaries and classifications based on findings on site
6. Map the full pilot area

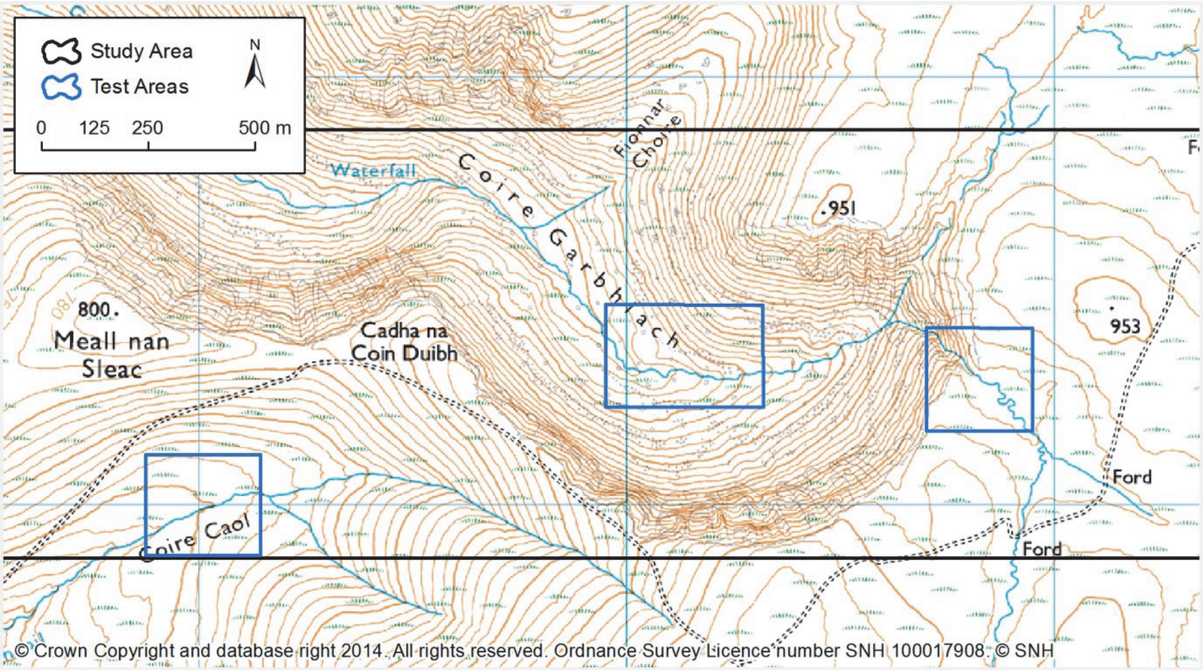


Figure 4. Reference (Test) areas within the Glenfeshie trial area.

3.4 Development of Indicators (Step 4), Delineation (Step 5) and Classification (Step 6)

Development of indicators (Step 4), delineation (Step 5) and classification (Step 6) of the habitats are described and discussed together as they were very much dependent on one another. At a later stage in the development of a method these stages would be more distinct even though there will always be a degree of interdependence.

Suggested interpretation indicators were identified for each of the habitats mapped. These are based on habitat characteristics that can be seen or deduced from the imagery in combination with ancillary data and, more importantly, knowledge of their ecology. The latter is a critical part of the interpretation and it is assumed that anyone using this approach is familiar with upland habitats and the situations in which they are likely to be found.

Due to lack of clarity over some habitat definitions it was not always possible to create final indicators that could fully separate similar habitats.

In the habitat accounts below, the habitat section heading (EUNIS classification) is followed by the relevant Annex I habitat code, in brackets. Any lower-level EUNIS classification types included within the main classification are listed immediately below the section heading.

The indicators considered most reliable are preceded by an asterisk. The additional indicators are also important but their occurrence tends to vary, e.g. hagged peat is a clear indication of bog habitat but not all peat bogs are hagged.

In the Figures in this section, contour lines are shown in order to illustrate topography.

When reading the following sections it is necessary to understand that:

- this is a draft set of indicators which requires further development based on field validation and re-interpretation of imagery,

- the indicators have been developed in and for a very small upland area and are not described in a Scotland-wide context, e.g. 'the habitat exists above 600m in the eastern uplands of Scotland' etc.,

- some ecological parameters are not mentioned as they are considered 'background knowledge' (i.e. upland areas, non-woodland etc.),

- some indicators are difficult to describe, such as the shape and surface of a blanket bog and it is again assumed that these will be recognised by the interpreter on the basis of previous knowledge and experience,

- the habitats in this study might have a slightly different set of interpretation indicators in different areas depending on species compositions, vegetation vigour etc. Hence, the indicators identified in this study should be reviewed when working in areas other than Glenfeshie,

- the indicators relating to the vegetation's appearance are relevant to mid-July imagery and will only partially apply to imagery captured at other times. If imagery from another time is to be used, the indicators relating to seasonal appearance need to be checked and potentially re-developed,

- the habitat mapping was based on manual interpretation of 25cm CIR imagery viewed in a digital photogrammetric stereo environment. The Figure examples in this report do not show the full level of detail of this data as they were created from orthorectified imagery of a lower resolution (50cm).

3.4.1 D1.2 Blanket bog (H7130)

D1.22 Montane blanket bogs, *Calluna* and *Eriophorum vaginatum* often dominant
D1.24 Wet bare peat and peat haggs on blanket bogs

The only type of blanket bog encountered in this area is D1.22 Montane blanket bogs, *Calluna* and *Eriophorum vaginatum* often dominant. However, the D1.22 bogs are often broken up and eroded into the EUNIS class D1.24 Wet bare peat and peat haggs on blanket bogs. It is worth noting that this class is a sub-category of D1.2 Blanket bog and not D1.22 which is the type of blanket bog within which it is now found.

3.4.1.1 Suggested interpretation indicators for D1.2 Blanket bog

D1.2 is a complex of several different types of bog vegetation and bare peat patches giving very different spectral signals (Figure 5). Below are generalised indicators for D1.22 and D1.24. Figure 6 gives a schematic view of what can be expected. As a whole the blanket bog (D1.2) should have:

- *Shape following the landscape topography, often located in valleys or larger depressions
- *Gentle gradient

3.4.1.2 Suggested interpretation indicators for D1.22 Montane blanket bogs, *Calluna* and *Eriophorum vaginatum* often dominant

- *Shape following the landscape topography, often located in valleys or hollows
- *Low gradient
- *Low productivity giving light grey-pinks to blue-grey tones (blue-grey tones can also come from some of the more silvery leaves of some typical blanket bog species such as *Eriophorum vaginatum* but also from litter from e.g. *Molinia caerulea*)
- *Grainy texture from an uneven surface that can be e.g. heather or graminoid tussocks - microbroken
- *Often a broken landscape with runnels and haggs
- *Often a mix of different vegetation with several different signals (speckled). Examples of components that contribute to the overall signal are areas of higher productivity along watercourses, peat haggs, bare peat, areas of incipient erosion, areas of full vegetation cover, areas of varying species because of moisture gradient etc.

3.4.1.3 Suggested interpretation indicators for D1.24 Wet bare peat and peat haggs on blanket bogs

- *Shape following the landscape topography, often located in valleys or 'hollows'
- *A clear green colour that will be lighter or darker depending on wetness (dry – wet)
- *Low gradient
- Where peat is completely bare: Smooth texture
- Where there are remnants of broken up vegetation or re-vegetation is taking place: Rougher texture, often grainy with light grey-pink 'dots'
- Peat haggs which are elevated features dropping down to eroded base of bare peat (the top of the haggs are often vegetated, i.e. pink)
- White bright patches on top of bare peat indicating fine particle mineral deposits

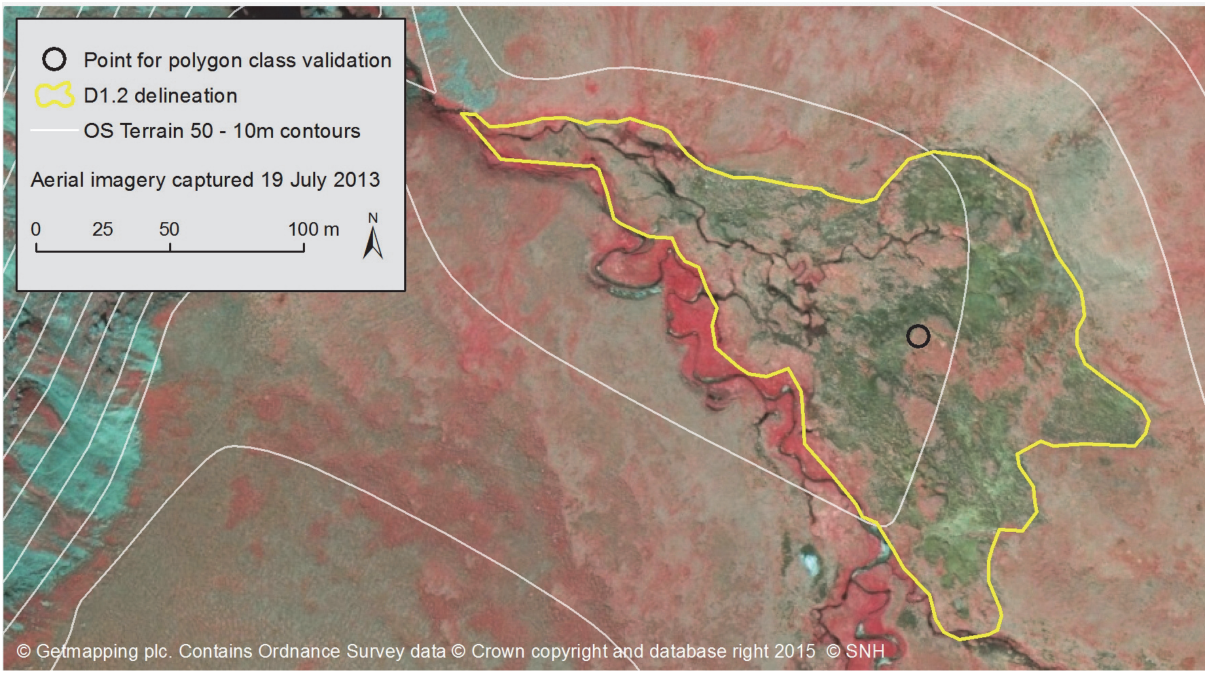


Figure 5. D1.2 Blanket bog polygon containing D1.22 Montane blanket bogs (pink) and D1.24 Wet bare peat and peat haggs on blanket bogs (green). Classification as well as boundary is correct (1) according to both validation teams.

3.4.1.4 Suggested mapping approach D1.2 Blanket bog

- When D1.22 and D1.24 are highly intermixed try to delineate the polygon so that one habitat dominates, designate this as the primary habitat, and designate the other as a secondary habitat based on a threshold coverage (e.g. >30%)
- Delineate the habitat using breaks of slope
- Delineate all bare peat, not just wet.

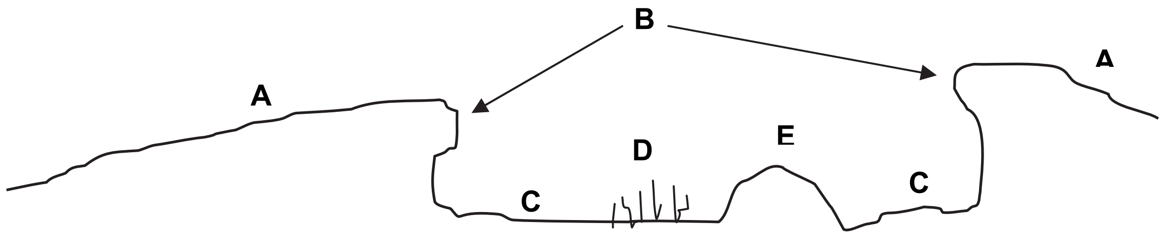


Figure 6. Schematic section through a blanket bog with eroding, remaining and re-vegetated features.

A) D1.22 Montane blanket bogs or other type of vegetation supported by peat (E4.32 and E4.21 below).
B) D1.24 Peat haggs on blanket bog.
C) D1.24 Wet bare peat in blanket bog. This feature can be sparsely vegetated (D) creating a transition towards D1.22.
E) Remaining hummock, bare or re-vegetated, amongst the D1.24 Bare peat. May be D1.22 or other type of peat supported vegetation (E4.32 and E4.21 below).

3.4.2 D2.2C Soft water spring mires (Non-Annex 1 habitat)

D2.2C Soft water spring mires can occur alone or in association with a stream. This habitat might be hard to identify since occurrences are small (at the pilot site) without any obvious signifying indicator which makes it easy to confuse with other types of very wet patches (Figure 7). Further reference areas and additional information on ecological characteristics such as where and how the habitat normally occurs are required to develop indicators.

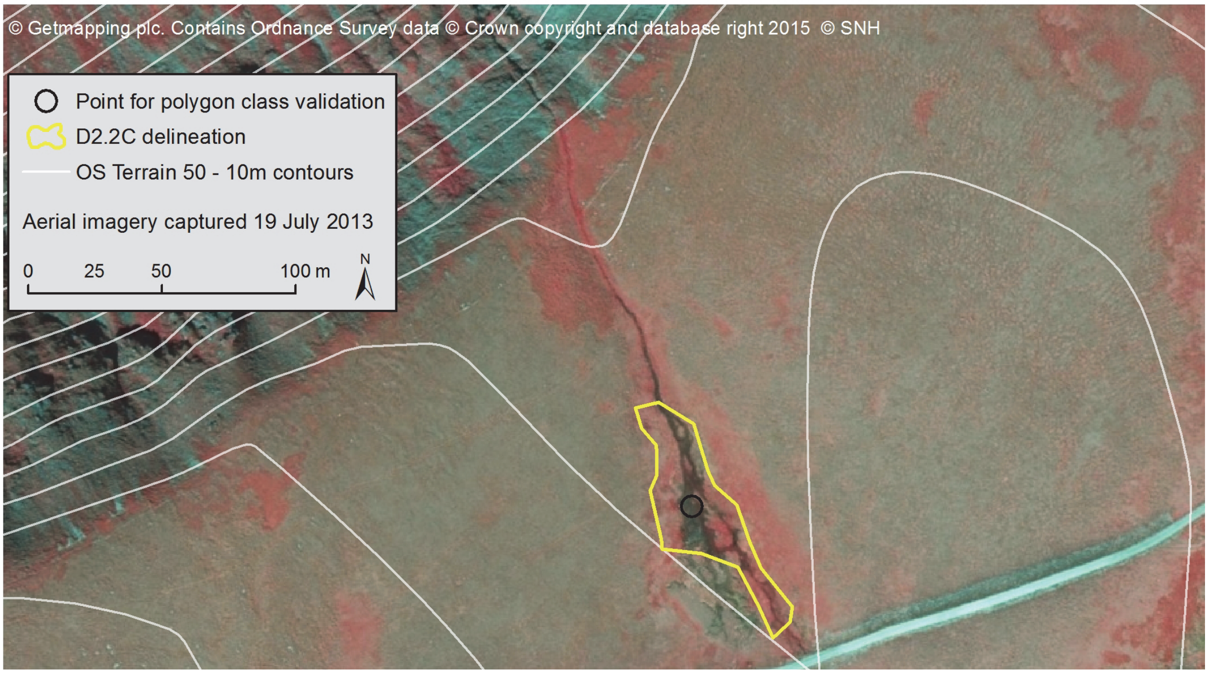


Figure 7. D2.2C Soft water spring mires.

3.4.3 E4.21 Oroboreal Carex bigelowii *– Racomitrium moss-heaths (H6150)*

There is a lot of scope for identifying areas with *Racomitrium* moss. However, where there is higher graminoid cover within the moss-heath it can be confused with E4.32 Oroboreal acidocline grassland (also H6150). These two habitats also often merge in a transition zone. For CIR reference for E4.21 and E4.32, see Figures 8 and 9.

3.4.3.1 Suggested interpretation indicators for E4.21 Oroboreal *Carex bigelowii – Racomitrium* moss-heaths

- *Mountain plateau or ridge
- *Uniform areas of low growing, fairly smooth appearance, with or without hummocks (elongated hummocks can give a creased impression)
- *Light blue-grey-green even colour
  - With *Vaccinium myrtillus* interspersed the moss heath turns to dull grey-red
  - Patches between moss hummocks can have graminoids giving a pink spider web impression
- There can be bare mineral or stone patches interspersed within the moss-heath

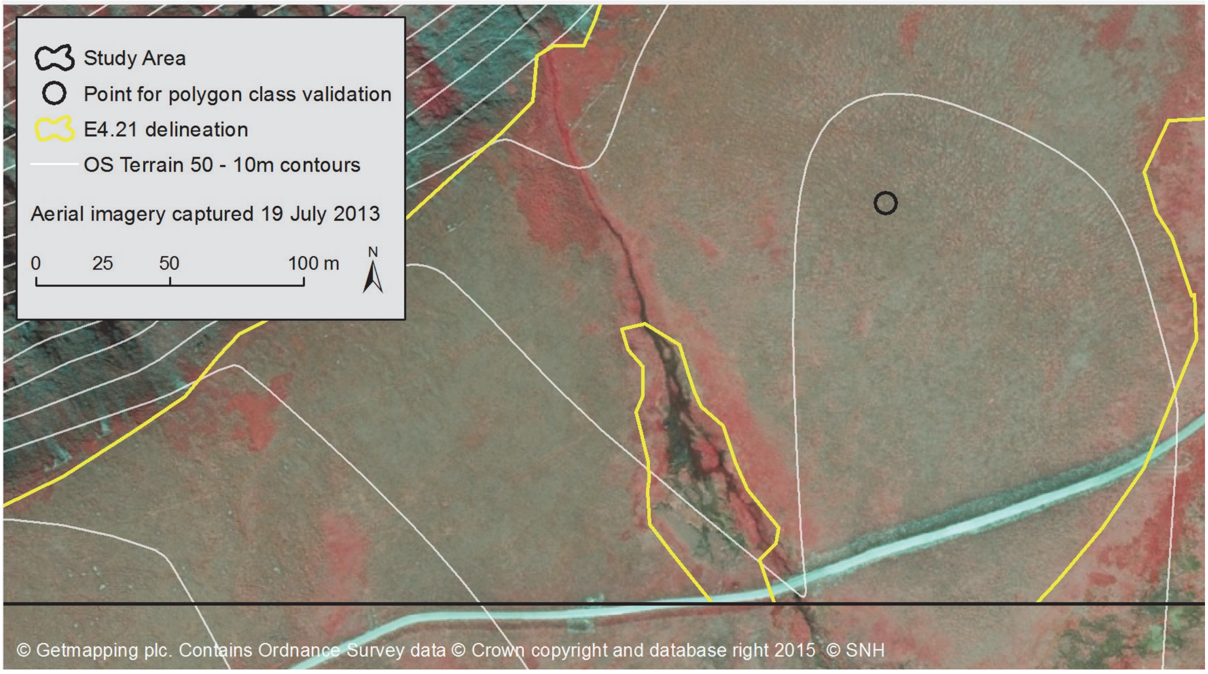


Figure 8. E4.21 Oroboreal Carex bigelowii – Racomitrium *moss-heaths within yellow boundary. Classification as well as boundary is correct according to both validation teams.*

3.4.3.2 Suggested mapping approach

- Delineate the habitat using breaks of slope
- If and when E4.21 and E4.32 are too difficult to separate, map them as the newly created EUNIS habitat complex E4.32€ Siliceous alpine and boreal grasslands which corresponds to the Annex I habitat H6150 with the same name.

3.4.4 E4.32 Oroboreal acidocline grassland (H6150)

E4.32 Oroboreal acidocline grassland is often found neighbouring and transitioning into E4.21 which means it can be difficult to draw a boundary between the habitats. This is especially the case when the E4.32 contains species with lower productivity giving a more blue-grey impression mimicking E4.21. For CIR reference for E4.21 and E4.32, see Figures 8 and 9.

3.4.4.1 Suggested interpretation indicators for E4.32 Oroboreal acidocline grassland

- *Mountain plateau
- *On slightly steeper slopes than E4.21, often where slope increases below E4.21 on flatter ground
- *Uniform areas of low growing, fairly smooth appearance, with or without tussocks
- *Pale pink (low productivity) with smudges of stronger pink (*Nardus*)
- *Blue-green tinge (mosses and *Carex* species)
- Deer grass (*Trichophorum cespitosum*) patches can sometimes be seen as distinct brown-beige-yellow grainy patches (not limited to this habitat though)

Separate from blanket bog, which has a grainy texture, by its smoother, micro-tussocky appearance.

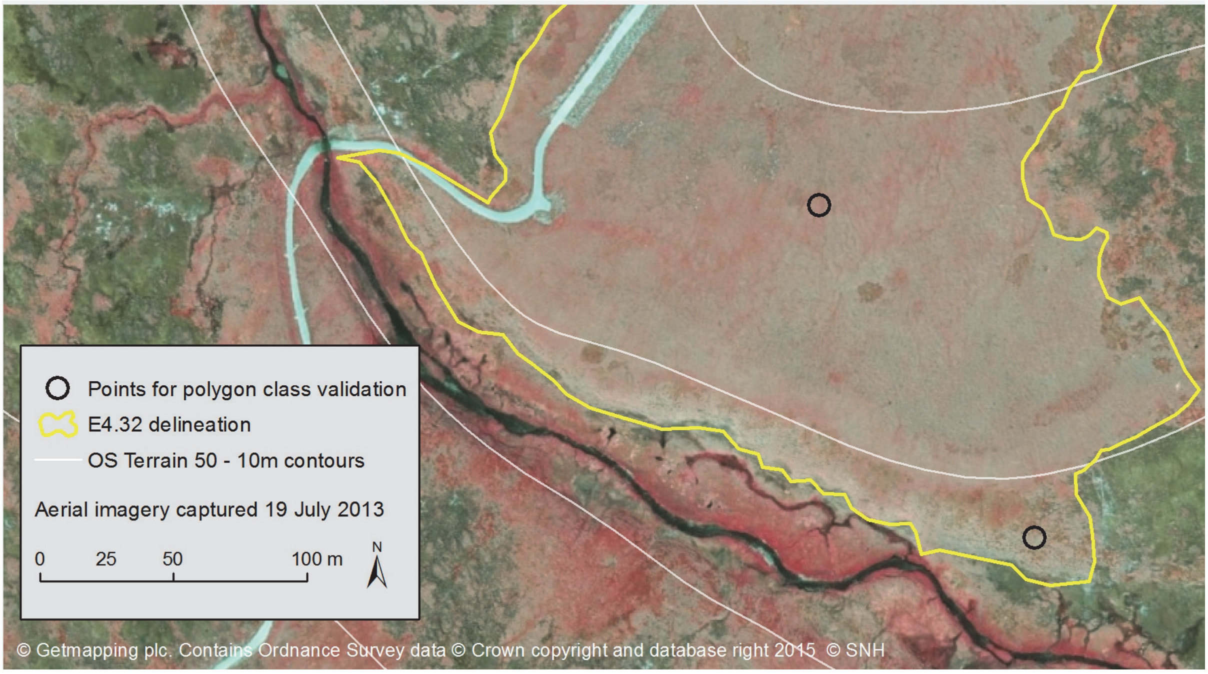


Figure 9. E4.32 Oroboreal acidocline grassland within yellow boundary. Classification is correct according to both validation teams. There are also patches of E4.21 within the polygon (according to both validation teams).

3.4.4.2 Suggested mapping approach

- If and when E4.21 and E4.32 are too difficult to separate, map them as the newly created EUNIS habitat complex E4.32€ Siliceous alpine and boreal grasslands which corresponds to the Annex I habitat H6150 with the same name.

3.4.5 E4.116 Boreo-alpine Deschampsia-Anthoxanthum *communities and or D2.22* Carex nigra, Carex canescens, Carex echinata *fens (Non-Annex 1 habitats)*

Two polygons were delineated as E4.116 Boreo-alpine *Deschampsia-Anthoxanthum* communities. This is a snowbed community which often fringes streams. In Glenfeshie we came across two examples of this grassland that were readily identifiable (Figure 10). However, Validation 1 classified the two areas as a mix of E4.116 and D2.22 *Carex nigra*, *Carex canescens*, *Carex echinata* fens. Validation 2 only visited one of the areas and classified it as D2.22 only. This makes it difficult to draw any conclusions so no attempt to interpret the results or set out indicators has been made, although this vegetation is clearly distinctive and future work will enable clarification.

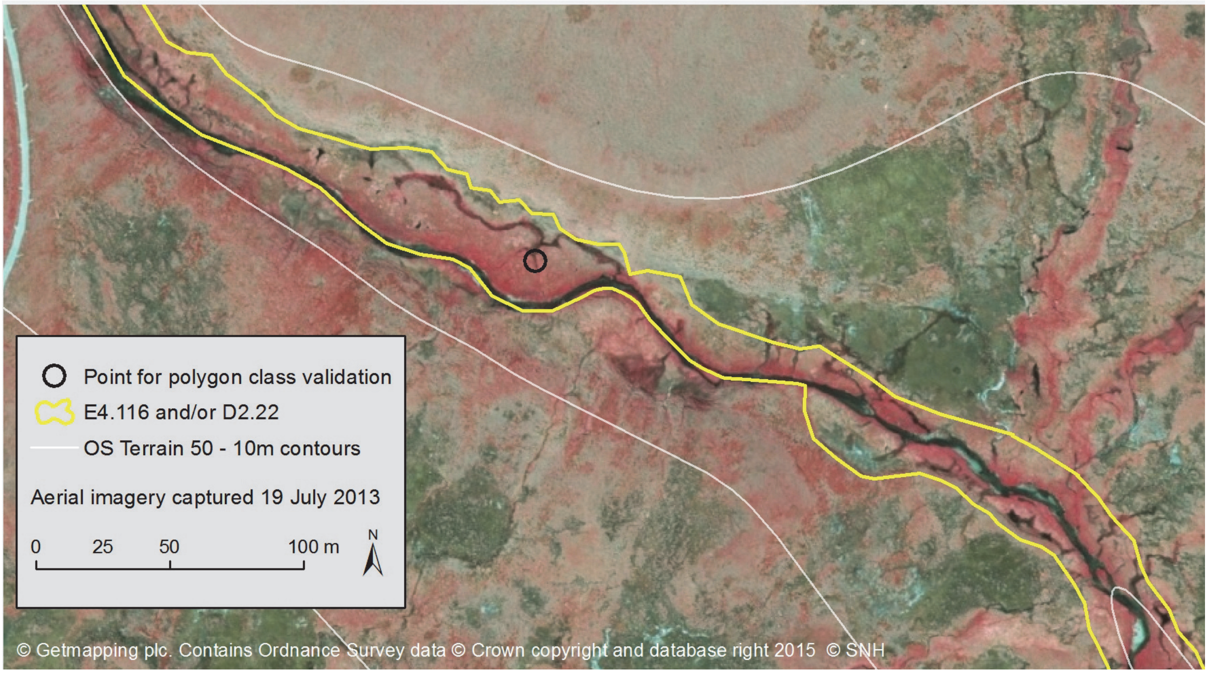


Figure 10. E4.116 Boreo-alpine Deschampsia-Anthoxanthum *communities and/or D2.22* Carex nigra, Carex canescens, Carex echinata *fens*

3.4.5.1 Suggested mapping approach

- Small narrow patches fringing watercourses within more extensive D1.2 Blanket bog should be generalised into the D1.2 habitat.

3.4.6 E5.59 Oroboreal tall-herb communities (H6430)

E5.59 Oroboreal tall-herb communities usually occur in small patches on crags and cliff ledges, often associated with areas of chasmophytic vegetation on rocky slopes (Section 3.4.11). Because of shadows on rocky slopes and also the limited patch extent of this habitat we are likely to only identify a fraction of it. This means it will be very difficult to map the whole extent of the habitat, but it will often be possible to map polygons in which the habitat occurs. For CIR reference see Figure 11.

NOTE: This habitat has not been mapped in the trial as it falls within the corrie which was excluded from the final mapping due to time limitations.

3.4.6.1 Suggested interpretation indicators for E5.59 Oroboreal tall-herb communities

- *Saturated red colour
- *Soft, furry texture indicating tall vegetation
- *On and around ledges and steep ground on cliffs and rocky slopes, and along streams

3.4.6.2 Suggested mapping approach

- Map the presence of E5.59 as an attribute separate from the dominant habitat within the polygon. There could be a three classes approach: 1) Present, 2) Possibly present, 3) Not present.
- If suitable, estimate the extent of the habitat within the polygon, or use a default percentage in order to obtain an area estimate.

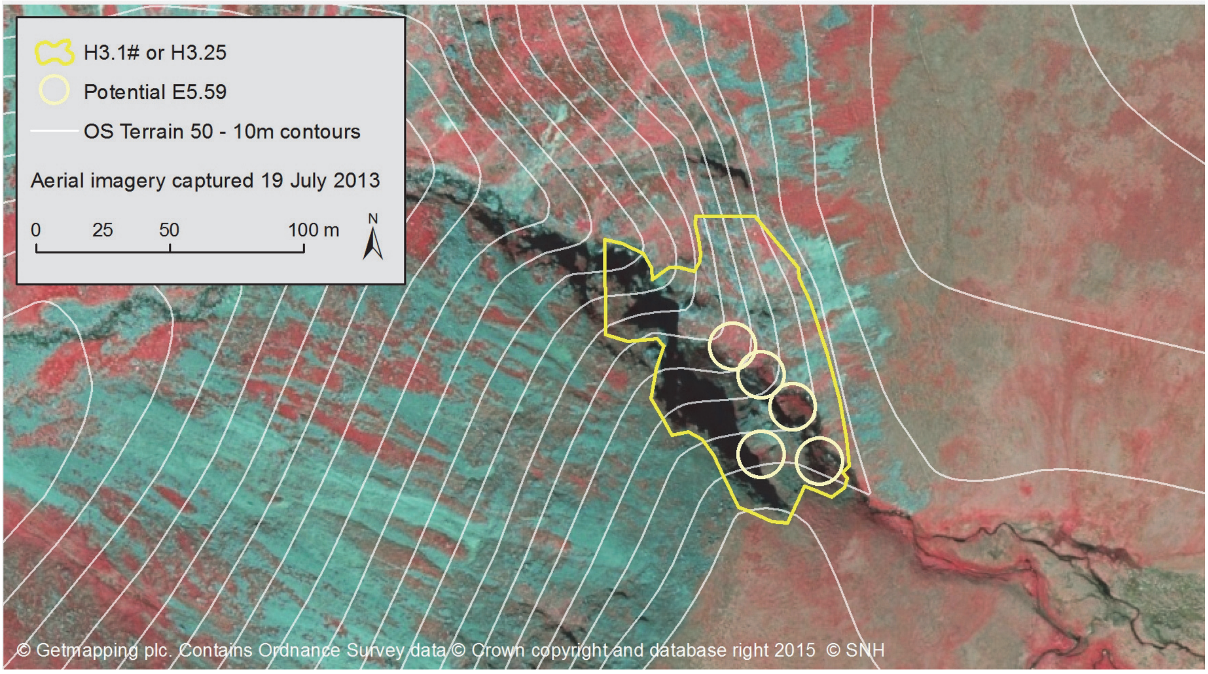


Figure 11. Polygon delineating rocky slopes with chasmophytic vegetation (either H3.1# / H8220 or H3.25 / H8210) within yellow boundary. White circles illustrate areas with potential and confirmed E5.59 Oroboreal tall-herb communities (H6430). Within this polygon F2.1# Sub-arctic Salix *spp. scrub can also be found but this has not been separated from other vegetation here. Note the shaded cliff face, where both H3.1# and patches of E5.59 can potentially be found.*

3.4.7 F2.1# Sub-arctic Salix *spp. Scrub (H4080)*

We observed the priority habitat F2.1# Sub-arctic *Salix* spp. scrub (H4080) within the corrie. It is possible to identify some scrub in the stereo imagery although it might be difficult or impossible to identify specific scrub habitats which occur in small patches without field confirmation. However, the different site conditions preferred by different scrub types could be used to develop indicators.

Scrub has not been mapped in the trial as it falls within the corrie which was excluded due to time limitations.

3.4.7.1 Suggested mapping approach

The location of many of the examples of this habitat is known and this information can be incorporated into the map. Unless future work shows that the habitat is suitable to map with points it is suggested that scrub habitats should be treated similarly to E5.59, i.e.

- Except for the very few examples of this habitat which are not small fragments, map the presence of F2.1 as an attribute separate from the dominant habitat within the polygon. There could be a three classes approach: 1) Present, 2) Possibly present, 3) Not present.
- If suitable, estimate the extent of the habitat within the polygon, or use a default percentage in order to obtain an area estimate.

3.4.8 F4.2 Dry heaths (H4030)

F4.2 Dry heaths (H4030) and F2.25 Boreo-alpine and arctic heaths (H4060) are both dwarf-shrub-dominated habitats, and can also share other species and characteristics. While in most circumstances it is straightforward to separate these habitats on the ground, they can have many species in common, and where they meet there are often transition zones where the habitats grade into one another; patches of F4.2 in sheltered situations within a matrix of F2.25, and patches of F2.25 in exposed situations within a matrix of F4.2. This can make mapping, especially delineation, difficult, particularly where boreal heaths, which can develop below the postulated former treeline, are present.

For practical purposes, this project aimed to treat dwarf-shrub-dominated communities which were wind-clipped, showing short or prostrate growth, or evidently in exposed locations (i.e. those considered likely to be above the postulated former treeline) as F2.25/H4060 and those not showing these characteristics as F4.2/H4030.

CIR references for F4.2 and F2.25 are shown in Figure 12.

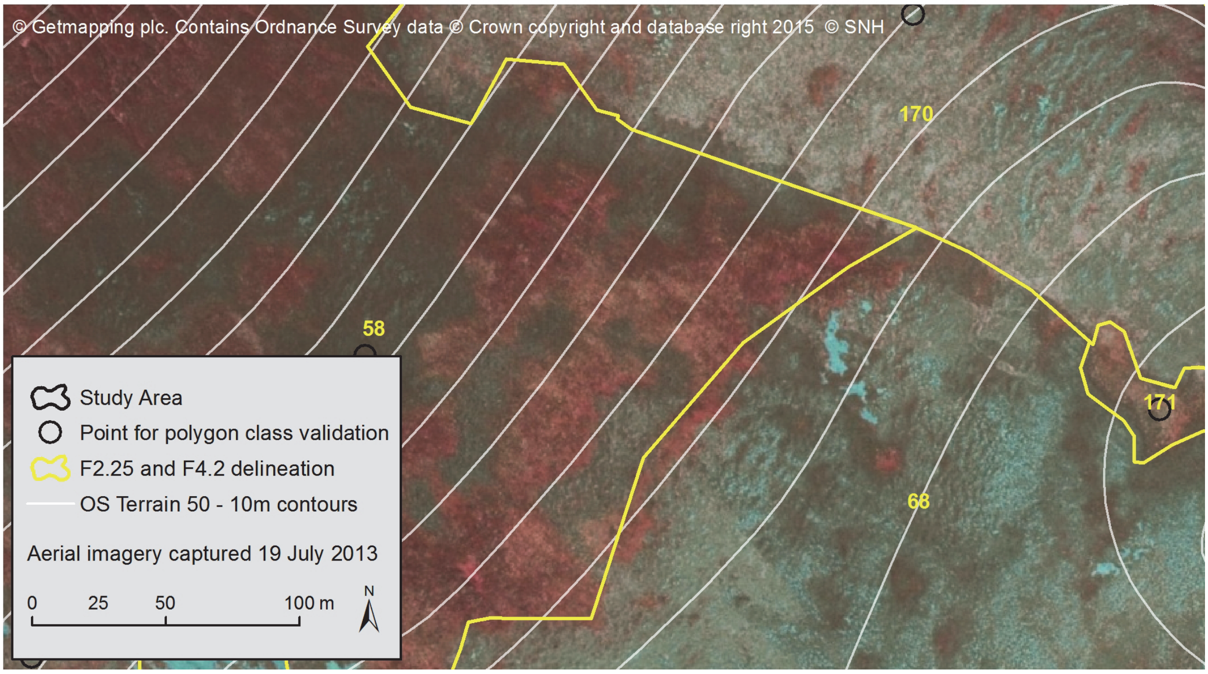


Figure 12. Delineated heath polygons. ***Polygon 58*** *interpreted as F4.2: Validation 1 classified the polygon to mainly F4.2 with patches of other habitats in the specific control points, Validation 2 classified it as dominated by F2.25* ***Polygon 68*** *interpreted as F2.25: Validation 1: Dominating habitat F2.25, Secondary habitat F4.2, Validation 2: F2.25 only.* ***Polygon 170*** *interpreted as F2.25: Validation 1: Dominating habitat F2.25, Secondary habitat F4.2, Validation 2: F2.25 only.* ***Polygon 171*** *interpreted as F4.2: Validation 1: Dominating habitat F4.2 and D1.22, Validation 2: F2.25 only.*

3.4.8.1 Suggested interpretation indicators for F4.2 Dry heaths

- *On moderate-steep slopes,
- *Upright, often tall-growing *Calluna* (grey-green to brown-red depending on vigour): Rough texture with a patchy pattern (individual shrubs).

Species growing below the canopy will alter the spectral signal of the heath; for *Vaccinium myrtillus* to brighter red and for *Sphagnum* to yellow-brown.

When interpreting heaths it is important to be aware of the effect of burning and how it alters the habitat and its regrowth. In Glenfeshie a burnt patch of F4.2 which is in the early stages of regrowth has strong affinities with F2.25. How these areas should be dealt with needs to be analysed and discussed further.

3.4.8.2 Suggested mapping approach

Based on validated results (Section 3.6) it is clear that the separation of F4.2 and F2.25 needs to be developed further. No suggestions on mapping approach are therefore given at this stage.

3.4.9 F2.25 Boreo-alpine and arctic heaths (H4060)

Discussion on separating this habitat from F4.2 appears in section 3.4.8 above.

Boreo-alpine and arctic heaths are found in exposed situations above and around the treeline and can consist of several different vegetation communities giving different signals, from light grey and pink to bluish tones.

CIR references for F4.2 and F2.25 are shown in Figure 12.

3.4.9.1 Suggested interpretation indicators for F2.25 Boreo-alpine and arctic heaths

- *Tops of mountains and mountain ridges and slopes
- *Very exposed locations
- *Low green vegetation (*Empetrum nigrum*, *Vaccinium myrtillus*, *Arctostaphylos uva-ursi*) which on its own gives a very pink to red signal but with increasing lichen and/or *Racomitrium* cover or interspersed small bare soil/rock patches turns to weak pink to light blue-green and also white in places)
- *Larger patches of non-vegetated bedrock or loose mineral (blue)
- *Low wind-clipped *Calluna* (rough texture with a regular patchy pattern throughout). (This indicator requires further elaboration to help differentiation from F4.2.)

3.4.9.2 Suggested mapping approach

Based on results (Section 3.6) it is clear that the separation of F4.2 and F2.25 needs to be developed further. No suggestions on mapping approach are therefore given at this stage.

3.4.10 H2.31€ Alpine siliceous screes (H8110) and H2.4 Temperate-montane calcareous and ultra-basic screes (H8120)

Scree is generally quite easy to identify both in stereo imagery and in orthophotos (Figure 13). However, it was found that in certain cases scree can be confused with rocky slope (H3.1# and H3.25). In these instances stereo can help to separate the habitats with greater confidence.

There are two types of screes in this area; siliceous (H2.31€) and calcareous (H2.4). There is no way to identify the acidity of the rock in the aerial imagery so ancillary data or field visits must be used in order to allocate a scree polygon to one or the other class.

3.4.10.1 Suggested interpretation indicators for H2.31€ Alpine siliceous screes and H2.4 Temperate-montane calcareous and ultra-basic screes

- *On steep slopes
- *Accumulations of loose non-vegetated material (boulders to fine grain sizes) (intense tropical sea blue colour) derived from rock weathering further up the slope
- *Often in talus formation

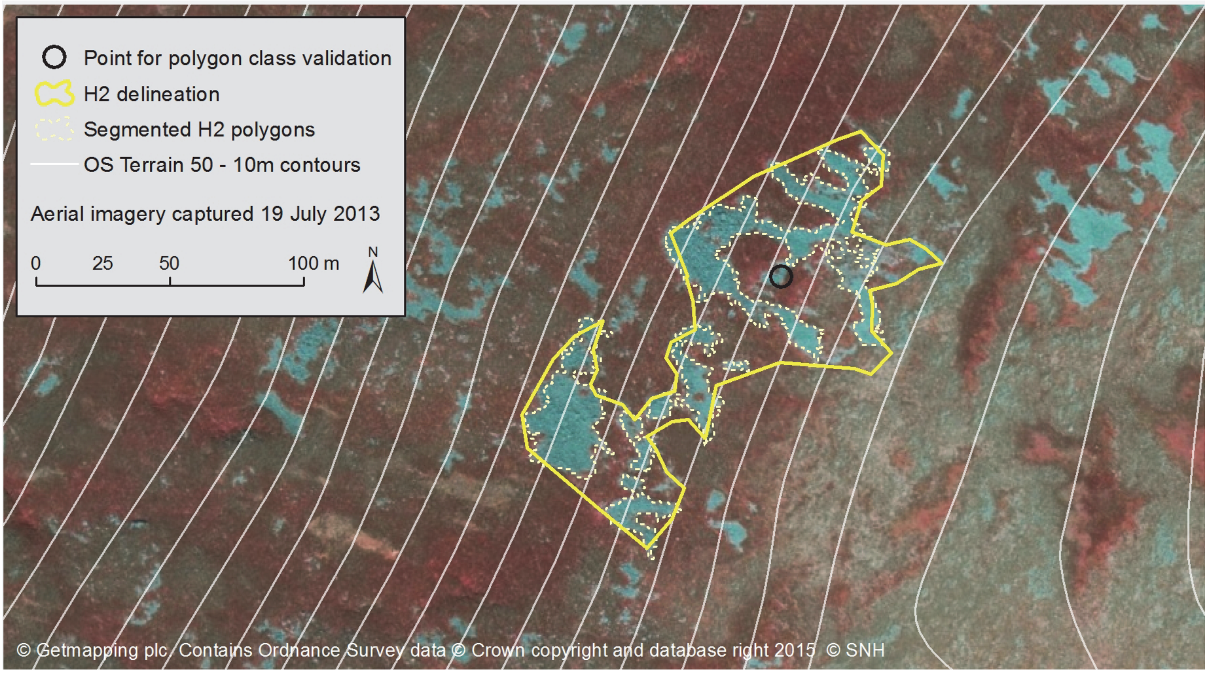


Figure 13. Area with several small scree patches. Scree with manually delineated boundary (strong yellow line) and automated image segmentation (dashed pale yellow line).

3.4.10.2 Suggested mapping approach

Screes are often elongated strips of varying width running down steep slopes. They are intricately interspersed with equally variable bands of vegetation. Even though it is simple to separate the scree strips from the vegetated ones visually it is time-consuming to manually delineate them. Automated image segmentation produces a more precise boundary in comparison to the manually drawn one which has included surrounding heath vegetation in the polygon (Figure 13). The clear blue signal of scree along with the crisp boundary to vegetated (red) patches makes it ideal to delineate using segmentation. There might be some confusion between scree and rocky slopes but the polygons can easily be checked in aerial imagery and if necessary edited. Even if checks have to be made, a segmentation approach should save a substantial amount of time compared to the time it would take to delineate the boundaries manually.

3.4.11 H3.1# Siliceous rocky slopes with chasmophytic vegetation (H8220) and H3.25 Alpine and sub-mediterranean chasmophyte communities (H8210)

As with screes, rocky slopes with vegetation (H3.1# and H3.25) are quite easy to identify (Figure 14), and similarly they cannot be separated into calcareous or siliceous habitats without ancillary geological data or field visits. As calcareous bands can occur within siliceous rocks, the two habitat types can coincide on the same rock outcrop.

Some fern-dominated patches of H3.1# and H3.25 may give a similar signal to that of E5.59 Oroboreal tall-herb communities. Further investigation into the appearance and occurrence of E5.59 and fern-dominated examples of H3.1# and H3.25 needs to be made in order to conclude whether a separation is possible in stereo or if final classification has to be made in the field.

NOTE: These habitats have not been mapped in the trial as they fall within the corrie which was excluded due to time limitations.

3.4.11.1 Suggested interpretation indicators for H3.1# Siliceous rocky slopes with chasmophytic vegetation and H3.25 Alpine and sub-mediterranean chasmophyte communities

- *Rocky slopes (blue-grey) with patches of vegetation (pink-red, non-tall)

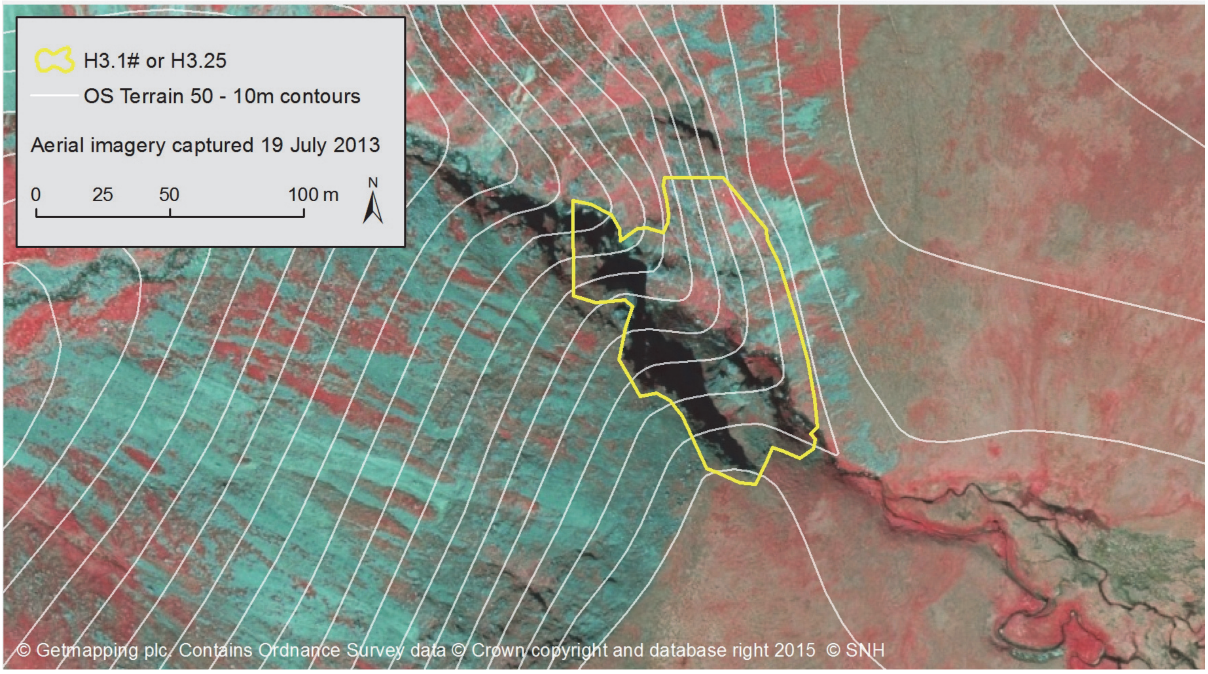


Figure 14. Area with rocky chasmophytic vegetation (H3.1# or H3.25) but also patches of E5.59 Oroboreal tall-herb communities (also see figure 11) and F4.2 Dry heath.

3.4.11.2 Suggested mapping approach

This habitat is a mosaic of bare rocky slope and patches of vegetation. However, the vegetation patches are not always chasmophytic but quite often F4.2 Dry heath. Since the rocky slope habitats are scarcer and of much lesser extent than the heath habitats it is suggested that the fragmentary rocky slope habitats should take precedence over the extensive, more common F4.2 in the polygon classification.

3.5 Delineation (Step 5) and Classification (Step 6) – general points

3.5.1 Issues

As there was no previous relevant work in this environment on which to base rules, no minimum mapping units were used and no definition of what constituted a 'dominating' habitat was set down. This may have led to some inconsistencies in the way polygons were mapped and classified, but was considered an unavoidable consequence of the need to explore possibilities.

Individual Scottish upland habitat types range from the extensive to the small and fragmentary. A large proportion of vegetation cover occurs as habitat mosaics. Depending on the objectives of the map, there are several ways of dealing with mosaics, from noting down each and every habitat occurring in a polygon to generalising and classifying the polygon to the dominating habitat. The latter can however be difficult if the mosaic is an intricate mix of two or more habitats, and will greatly under-represent or omit entirely habitats which only occur as minor components of polygons or as small and fragmentary occurrences. These factors make delineation and classification highly complex and open to individual interpretation (whether in the field or by imagery interpretation). If different mappers (or indeed the same mapper on different occasions) interpret the environment differently, the consequence will be a lack of consistency.

In order to avoid inconsistencies, clear rules on minimum mapping units, dominating habitat coverage, how to map mosaics, dealing with fragmentary habitats etc. are required.

3.5.2 Linear habitats and features

It is common practice in vegetation mapping to include roads and tracks and their disturbed vegetated verges into larger polygons and to expect the user to understand that the habitat may be different alongside the constructed linear features. This approach was followed in this exercise.

Narrow strips of vegetation that fringe water courses and differ from more extensive surrounding vegetation are seldom mapped separately in vegetation maps, although they may be recorded as forming part of a mosaic. This can be partly a scale (strip width) issue, but is also often because it is expected that the user will appreciate that vegetation adjacent to the watercourse will be different from that of the rest of the area.

In many cases there will be no particular benefit in mapping these linear habitats as separate polygons but there will be occasions when the fringing vegetation will be of a size that deserves mapping. In this exercise, wider occurrences of E4.116 Boreo-alpine *Deschampsia-Anthoxanthum* communities fringing watercourses were mapped, while narrow marginal strips were not. Another option would be to map linear features as linear objects, but only polygons were used here.

Using minimum mappable units can help determine when a habitat, for example a linear habitat alongside a burn, should be mapped. Given that a long narrow strip of vegetation will produce a large total area if the linear feature they run along is long enough, a minimum width of habitat can also be included as a criterion applied to all polygons. What is important is that rules (which may differ between habitat types) are clearly set out and that their consequences are evident to both producers and users of the resulting map.

Watercourses, roads and tracks were not mapped in this exercise as they are represented in many other high quality datasets such as Ordnance Survey MasterMap.

3.6 Field control (Step 7) and Analysis of interpretation and accuracy assessment (Step 8)

This section compares and discusses the results from the two teams of surveyors, who were tasked with validating the same set of polygons. It then describes an accuracy assessment of the stereo interpreted map based on the points where there was full agreement between the two field validation teams. The interpreted EUNIS-coded map is shown in Figure 15, with an enlarged version in Appendix 2. Maps showing polygon and validation point IDs and field records from both validation teams form part of the additional material associated with this report and available from SNH.

The second team of surveyors did not manage to visit all points due to weather conditions and short days. However there are 43 mutual point checks for comparison of classes and 38 for comparison of boundaries.

The Validation Teams were asked to score boundaries according to their degree of agreement with them thus:

- 1 – ‘Correct’
- 2 – ‘Acceptable’
- 3 – ‘Unacceptable’

Validation 1 (i.e. the first team of surveyors) sometimes used intermediate grades, making a comparison with Validation 2 slightly more complicated. Strict rules might have avoided this, but may also have constrained the learning aspect of the trial. In order to simplify, ‘1-2’ is interpreted as 1 (‘Correct’) and ‘2-3’ as 3 (‘Unacceptable’).

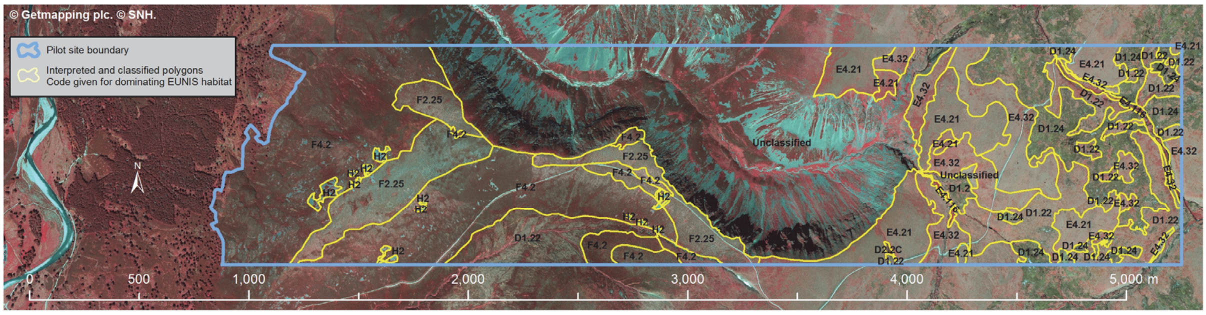


Figure 15. Stereo infra-red aerial imagery interpreted boundaries and EUNIS classification. (An enlarged version is available in Appendix 2.)

3.6.1 Boundaries – Validation 1 and Validation 2 results

In vegetation, clearly defined boundaries are rare, with changes in type usually occurring over transition zones of varying magnitude. Therefore, in habitat mapping defining the exact position of a polygon boundary relies to a greater or lesser extent on a judgement made by the surveyor, and it is common for this to result in some disagreement among surveyors as to the exact position of boundaries.

All but three of 38 polygon boundaries were considered ‘Correct’ by Validation 1 (Table 3). These three were still considered ‘Acceptable’. Most of the boundaries were considered to be in the right place and errors were considered to be small.

Validation 2 was more critical of the boundaries (Table 3) and considered that several patches of different habitats should be merged into neighbouring polygons and that additional polygons should have been drawn within other polygons. Sometimes misclassifications rather than boundaries *per se* are the cause of the boundary disagreements. Few of the suggested corrections represent a difference of more than 0.5 hectares (equivalent to a patch approximately 70m x70m) although for a few larger polygons the accumulated area of the boundary error is larger than a hectare.

Table 3. Boundaries – Comparison between Validation 1 and Validation 2 results.

Grade	**Validation 1 No. (%) of polygons**	**Validation 2 No. (%) of polygons**
Correct (1 & ‘1-2’)	37 (97)	10 (26)
Acceptable (2)	1 (3)	19 (50)
Unacceptable (3)	0 (0)	9 (24)
Number of points	38 (100)	38 (100)
Surveyor estimated accuracy Correct-Acceptable	**100%**	**76%**

3.6.2 Classification – Validation 1 and Validation 2 results

At first glance it seems that Validation 1 and 2 have reached roughly the same conclusion on overall accuracy of classification with Validation 1 at 65% for 'Correct to Acceptable' and Validation 2 at 70% (Table 4), but see this disguises some disagreement.

Table 4. Classification – Comparison between Validation 1 and Validation 2 results.

Grade	Validation 1 No. (%) of points	Validation 2 No. (%) of points
Correct (1 & '1-2')	21 (49)	23 (54)
Acceptable (2)	7 (16)	7 (16)
Unacceptable ('2-3' & 3)	15 (35)	13 (30)
Number of points	43 (100)	43 (100)
Surveyor estimated accuracy Correct-Acceptable	**65%**	**70%**

3.6.2.1 Point by point comparison of Validation 1 and Validation 2 results

In a point by point comparison of Validation 1 and Validation 2, variation in the validation results appears. This is partly because Validation 1 has taken a mosaic approach and given a poorer score when e.g. a secondary habitat is present but not recorded. Validation 2 has, on the other hand, accepted the classification but given a poorer score for boundary classification, drawing a separate polygon for the secondary habitat. Therefore the two teams are giving poor scores for the same issue, but in different ways. Once these false disagreements are removed a few real classification disagreements are revealed.

In Table 5 the point by point comparison, and causes of disagreement, are summarised. This excludes points where there are false disagreements as described above. The identification of causes of disagreement is based on interpretation of the habitat classifications and comments given by the two teams.

Table 5. Interpreted class agreement between Validation 1 and Validation 2

Interpreted class agreement	Points (n=43)	Points (%)	Causes of disagreement
Full	23	54	
2 out of 3	1	2	Occurrence of F4.2 (1 point)
1 out of 2	10	23	Dominance of E4.116 (1 point) Assignment of D1.22 and D1.24 (2 points) Assignment of F2.25 and F4.2 (4 points) Assignment of E4.32 and E4.21 (1 point) Assignment of D1.22 and E4.32 (2 points)
1 out of ≥3	2	5	Assignment of D1.22/D1.24 and E4.32/E4.21 (2 points)
None	7	16	Assignment of F2.25 and F4.2 (4 points) Assignment of D1.22/D1.24 and E4.32/E4.21 (2 points) Assignment of D1.22 and E4.32 (1 point)

The comparison shows clear disagreement over classification of F4.2 and F2.25 as exposure increases. Where Validation 1 identifies more F4.2, Validation 2 identifies more F2.25 (Figure 12). This might be due to differences in how the original class definitions are interpreted and applied but it may also be due to disagreements arising from how mosaics and transition zones are mapped and recorded. A clear resolution of this issue will be required for future mapping.

There is also some disagreement over the classification of hagged areas where the original bog vegetation (which resulted in peat formation) has been replaced by montane acid grassland on the top of haggs, between which bare peat is found. One team tended to classify according to the vegetation on top of the haggs, i.e. E4.32 or E4.21, while the other classified it as D1.2 Blanket bog (which includes D1.24 Wet bare peat and peat haggs on blanket bogs). Both of the classifications are correct in their own sense but the confusion needs to be removed by either recording both habitats or by defining how haggs with vegetated tops not referable to blanket bog vegetation should be classified. One solution is to simply classify the habitat as the vegetation present on the hagg tops (E4.32 or E4.21). This would make sense as D1.24 by definition is blanket bog, and although deep peat remains in the above cases, the stage of degradation is such that it seems very unlikely that blanket bog vegetation will be restored on top of the haggs in the foreseeable future.

Another area of disagreement relates to some examples of D1.22 Montane blanket bog and E4.32 Oroboreal acidocline grassland, but there are too few sample points to show whether this is a systematic difference between the two surveyor teams. The same applies to a couple of points where the validation teams have disagreed on whether an area should be classified as E4.32 or E4.21, although this is perhaps less important as both habitats form part of the same Annex 1 habitat and they tend to merge over a transition zone.

3.6.3 Accuracy assessment of the stereo interpreted map where Validation 1 and Validation 2 agreed

An accuracy assessment of the stereo imagery interpreted map was made for the points where the validation teams fully agreed (Table 6). Seven points where there was disagreement between F2.25 and F4.2 were merged into a Heath class with one point where there was full agreement on F2.25. H2 and D2.2C only had one reference point each and were removed from the sample making a total of 29 validation points to assess (Table 6).

Table 6. Confusion matrix for CIR stereo imagery classification points (Classified Data) and validation team agreed classification points (Reference Data). Note that Reference Data include classes not identified in the Classification exercise. Figures represent the number of points for each class in each exercise. Green = agreement, Orange = partial agreement, Red = full disagreement.

		REFERENCE DATA						
		HEATH	D1.2	E4.21	E4.32	D1.2/ E4.32	E4.21/ E4.32	Row Total
CLASSIFIED DATA	HEATH	8						8
	D1.2		4			2	1	7
	E4.21			4	1		1	6
	E4.32				6		2	8
	Column Total	8	4	4	7	2	4	29

As an example, the table shows that out of six points classified as E4.21 in the CIR interpretation, four were correct according to the validation exercise, one was incorrect (E4.32) and 1 was partially correct (E4.21/E4.32), i.e. the classified habitat was actually one of two habitats in mosaic.

Acknowledging that the sample size is small, some patterns seem to emerge:

- Heath is easily distinguished, with all points correctly classified in the draft map
- Two points are completely misclassified but only one (E4.21/E4.32 classed as D1.2) results in subsequent misclassification of the Annex I habitat (E4.21 and E4.32 both form part of the same Annex 1 habitat, Montane acid grassland H6150).
- Five points are assessed as not correct because a second habitat occurring in mosaic is not recognised

3.6.4 Problems encountered in the validation exercise

Although the validation exercise was extremely useful several factors made both it and interpretation of the results difficult. Some of these factors flowed from the first identified below:

- It was not properly explained to the validation teams that an attempt to map only one dominating habitat in each polygon had been made. Vegetation surveyors are used to working with mosaics, and hence there was lower acceptance of classifications of polygons with a notable proportion of other vegetation types.

- One of the validation teams reported habitat extents of individual NVC communities. This sometimes made it difficult to assess the extent of EUNIS class(es).

- The grading system of 1) Correct, 2) Acceptable, 3) Unacceptable was not adhered to and intermediates were used, which made interpreting the results more difficult.

- Surveyors' reasons for assigning grades (i.e. 1, 2 or 3) were not always clear, making it difficult to assess some of the individual point assignments.

3.6.5 Overall conclusion on validation

The field validation showed that the interpretation indicators worked well for several habitats and that the overall accuracy at this early stage of method development is quite promising and likely to improve with further work.

Modification of some interpretation indicators will be required but some of the difficulties encountered can easily be resolved through the application of mapping rules. Some modification of indicators will be dependent on clear resolution of issues which have arisen in the course of the validation exercise, for example the separation of F4.2 (H4030) Dry heaths and F2.25 Boreo alpine and arctic heaths (H4060).

For subsequent studies, clear mapping rules and an appreciation of them by validation teams will enable better assessment of the accuracy of the desk-based polygon delineation and classification. Clear rules will also help standardise the accuracy assessment, minimising some of the inevitable variance between field surveyors.

3.7 Overview of potential for Annex I identification in CIR stereo imagery

The potential for identifying the targeted Annex I habitats using CIR stereo imagery shown by this trial is summarised in Table 7. (The individual EUNIS habitats making up the Annex I and non-Annex I habitats and their identification potential are discussed in Section 3.4.) The small sample size available in the restricted pilot area should be borne in mind.

Table 7. Summary of potential to identify Annex I habitats accurately. Note that this is based on characteristics displayed in Glenfeshie, and there may be some differences in other areas.

Annex I Code	**Annex I Name**	**Identification potential**
H4030	European dry heaths	Straightforward once separation from Alpine and Boreal heaths around treeline is resolved.
H4060	Alpine and Boreal heaths	Straightforward once separation from Dry heath around treeline is resolved.
H4080	Sub-arctic *Salix* spp. scrub	Not attempted.
H6150	Siliceous alpine and boreal grasslands	Fairly easy apart from slight confusion with grassy blanket bogs.
H6210	Semi-natural dry grasslands and scrubland facies: on calcareous substrates (*Festuco-Brometalia*)	Not found in imagery or on site visits.
H6230	Species-rich *Nardus* grassland, on siliceous substrates in mountain areas (and submountain areas in continental Europe)	Not found in imagery or on site visits.
H6430	Hydrophilous tall herb fringe communities	Rocky polygons potentially containing the habitat can be identified due to lushness of vegetation on the slopes.
H7130	Blanket bog	Fairly easy apart from a slight confusion with H6150 Siliceous alpine and boreal grasslands, particularly where they occur among hagged peat.
H8110	Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani*)	Scree easy. Ancillary data or site visit needed for base status.
H8120	Calcareous and calcshist screes	Scree easy. Ancillary data or site visit needed for base status.
H8210	Calcareous rocky slopes with chasmophytic vegetation	Rocky slopes with vegetation easy. Ancillary data or site visit needed for base status.
H8220	Siliceous rocky slopes with chasmophytic vegetation	Rocky slopes with vegetation easy. Ancillary data or site visit needed for base status.

4. DISCUSSION AND RECOMMENDATIONS

4.1 EUNIS and Annex I classification in Scotland

The EUNIS and Annex 1 classification systems are not supported by independent floristic or other data (Strachan, 2015) and therefore largely rely on correspondence with existing UK classification systems, mainly the National Vegetation Classification (NVC) (Rodwell, 1991-2000). EUNIS also includes classes for man-made and non-vegetated habitats not covered by the NVC. The EUNIS manual (Strachan, 2015) sets out correspondence between the NVC, EUNIS, and Annex I habitats in Scotland, but many of these are not simple one-to-one relationships.

The Manual is essential to understanding relationships but is made up largely of a series of conversion tables between different habitat classification systems. Additional explanation will be required to accompany the HabMoS in order for it to be useful to a wide audience.

Unsurprisingly, habitat and vegetation descriptions in existing classification systems often lack connections to physical structures visible in aerial photographs. They therefore need to be elaborated and transformed in order to create functional indicators for imagery interpretation (Skånes, Personal communication).

4.1.1 Recommendations

- As part of the Upland Mapping Project an upland mapping manual will be required. This will need to set out habitat descriptions that are clear from a mapping perspective and applicable to the methods used to capture the habitat in question. For habitats that are to be mapped by aerial imagery interpretation reliable interpretation indicators are required.

- Consideration should be given to how habitat classes identifed in the Habitat Map of Scotland (HabMoS) can be meaningfully presented and explained.

4.2 Polygon delineation and classification rules

In order to create a consistent map there has to be consistency in the method. This can be achieved by creating clear mapping rules, which represent the application of a compromise between the level of detail which exists in the real world and the practicalities of representing that world on a map. With a full scale pilot it would become clearer what rules can be used and what rules are too difficult to apply. Below are some rules that would have simplified the mapping, field control and accuracy assessment for the Glenfeshie area:

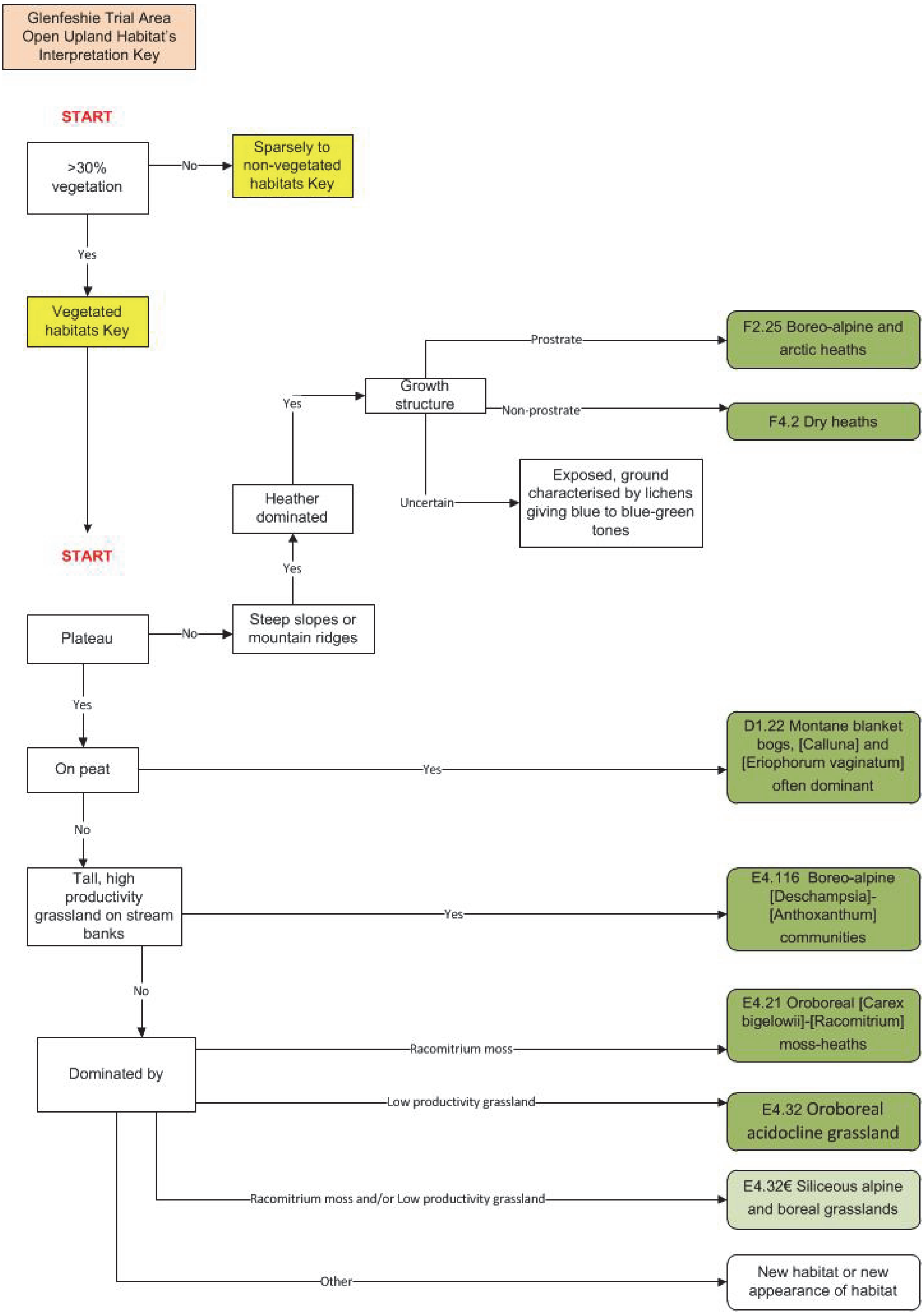
- Definition of minimum mappable units (MMU)
- Definition of dominating habitat (e.g. >50%).
- Rules on when to map secondary habitats (e.g. >30%) and how (e.g. record it in a secondary habitat column).
- Use smaller MMU for important fragmentary habitats or map them as 'present' or by using points, developing default percentages for extent calculations.
- For common mosaics where the habitats are intricately mixed in a patch-like manner it is difficult to map them as separate habitats. These could be assigned specific mosaic classes in order to map them as 'dominating'. This would also give information on the intrinsic nature of the mosaic.

4.2.1 Recommendations

- As part of an upland mapping manual, develop clear mapping rules to ensure an overall consistent result and higher mapping accuracy. By using mapping rules in conjunction with interpretation keys, individual differences decrease and this leads to higher quality data. Mapping rules also ensure that the method is repeatable.

- Clearly define what is to be mapped within the delineated polygons. For efficiency, different rules will apply according to the characteristics of habitats (for example widespread and extensive or scarce and fragmentary).

Figure 16 shows a preliminary aerial imagery interpretation key for Glenfeshie. This key has been created in order to illustrate how a key could work within a larger mapping project. It is neither fully developed nor tested and should at this stage be seen as a hypothetical example. A fully working key needs mapping rules, it also has to take additional habitats into account. Furthermore it has to be tested and re-tested in order to eliminate inconsistencies and routes leading to incorrect habitat classification.



Glenfeshie Trial Area
Open Upland Habitat's
Interpretation Key
START
>30% vegetation
No
Sparsely to non-vegetated habitats Key
Yes
Vegetated habitats Key
START
Plateau
No
Steep slopes or mountain ridges
Yes
Heather dominated
Yes
Growth structure
Prostrate
F2.25 Boreo-alpine and arctic heaths
Non-prostrate
F4.2 Dry heaths
Uncertain
Exposed, ground characterised by lichens giving blue to blue-green tones
Yes
On peat
Yes
D1.22 Montane blanket bogs, [Calluna] and [Eriophorum vaginatum] often dominant
No
Tall, high productivity grassland on stream banks
Yes
E4.116 Boreo-alpine [Deschampsia]-[Anthoxanthum] communities
No
Dominated by
Racomitrium moss
E4.21 Oroboreal [Carex bigelowii]-[Racomitrium] moss-heaths
Low productivity grassland
E4.32 Oroboreal acidocline grassland
Racomitrium moss and/or Low productivity grassland
E4.32€ Siliceous alpine and boreal grasslands
Other
New habitat or new appearance of habitat

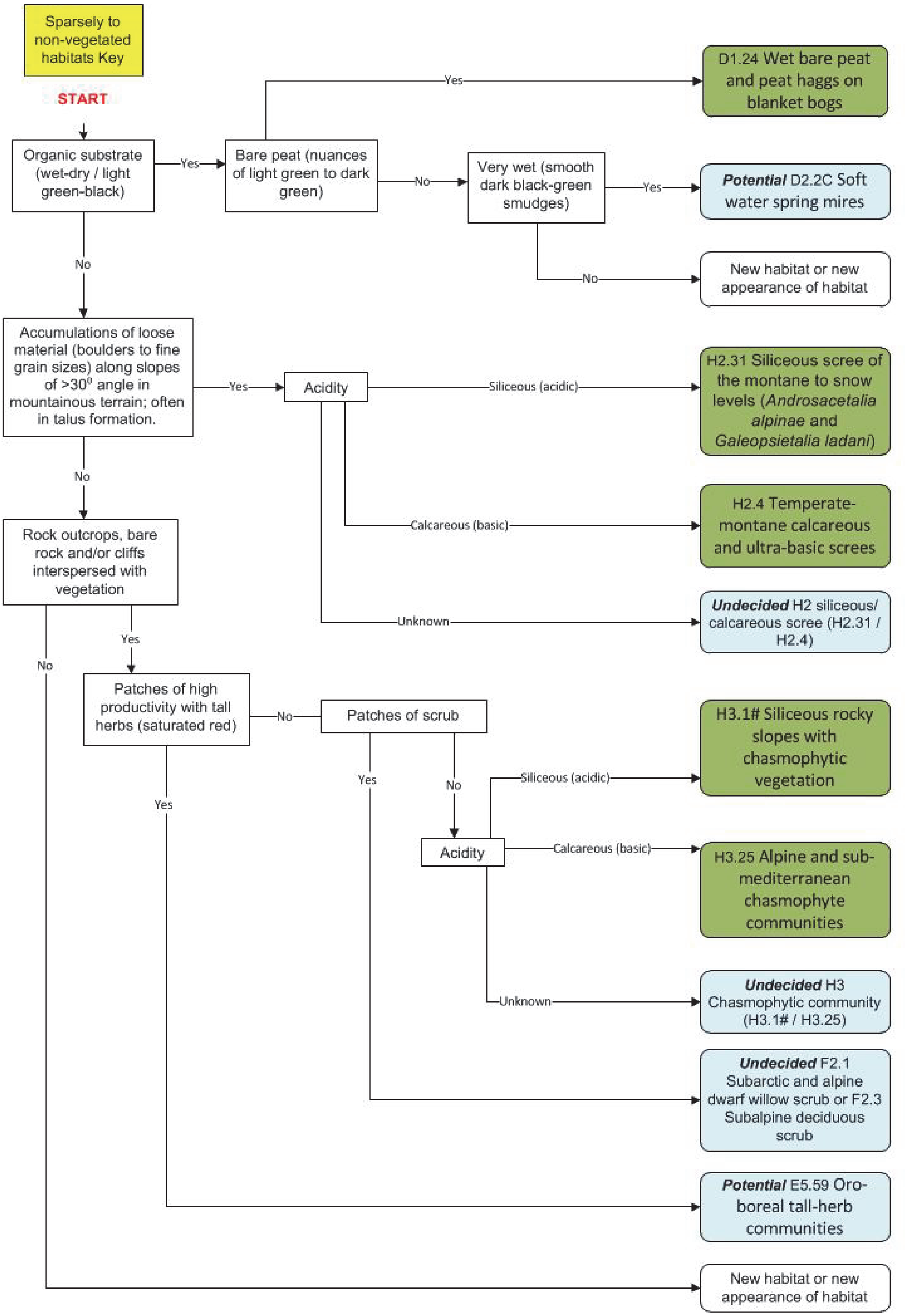


Figure 16. An example of a partial EUNIS habitat aerial imagery interpretation key for the Glenfeshie trial area. This key has neither been fully developed nor tested and is presented as an example on how an interpretation key could be built to ensure mapping consistency and hence increase overall mapping accuracy.

4.3 Information on habitat base status

Several rock habitats are separated according to whether they are calcareous or siliceous, and thus support vegetation characteristic of these conditions. This characteristic cannot be deduced from the aerial imagery and requires either ancillary geological data or site visits in order to determine species composition which cannot be identified in the imagery.

4.3.1 Recommendation

- Geologists should interpret and reclassify geological rock and soil datasets to separate calcareous (basic) from siliceous (acidic) areas. This approach could be tested within a full pilot and could either be done in-house or via a contract. However it should be noted that feedback and close discussion would be required with the SNH habitats team and this would need to be factored into any contract let.

4.4 Image segmentation as a delineation support

Unlike satellite data, aerial imagery does not provide radiometric information which can be manipulated to create a standardised method for segmentation to support delineation. However, segmentation of aerial imagery does allow exploration of the relationships between colour representation and habitats on the ground. Within an ongoing project (Making Earth Observation Work (MEOW) for UK biodiversity conservation Phase 3 led by JNCC), Environment Systems Ltd supplied SNH with an automated segmentation of the aerial imagery for the Glenfeshie study area.

An initial check of the segments shows that they follow habitats or variations of habitats quite well and that they are close to being fit for trial purposes. Bare peat forms its own EUNIS class, D1.24 Wet bare peat and peat haggs on blanket bogs. This class is included in the Annex I habitat H7130 Blanket bog and does not necessarily need to be separated from D1.21 or D1.22 if the only purpose is mapping Annex 1 habitats. However, in the segmentation process, areas of bare peat can be recognised and separated by colour in the CIR imagery (Figure 17). Currently there are, however, some bare peat polygons that have larger vegetated areas contained within them and the same applies to the converse situation. Separation of vegetated bog from bare peat through segmentation would be useful for various purposes. Similarly, bare scree occurs along with vegetated slopes in some polygons and again, a full separation is desirable as scree forms Annex I habitats. If possible minimum mappable unit rules should define the circumstances in which these habitats are merged in single polygons.

It was also observed that some of the boundary changes that the validation teams identified were reflected in the segmentation (Figure 17). This was, however, not always the case.

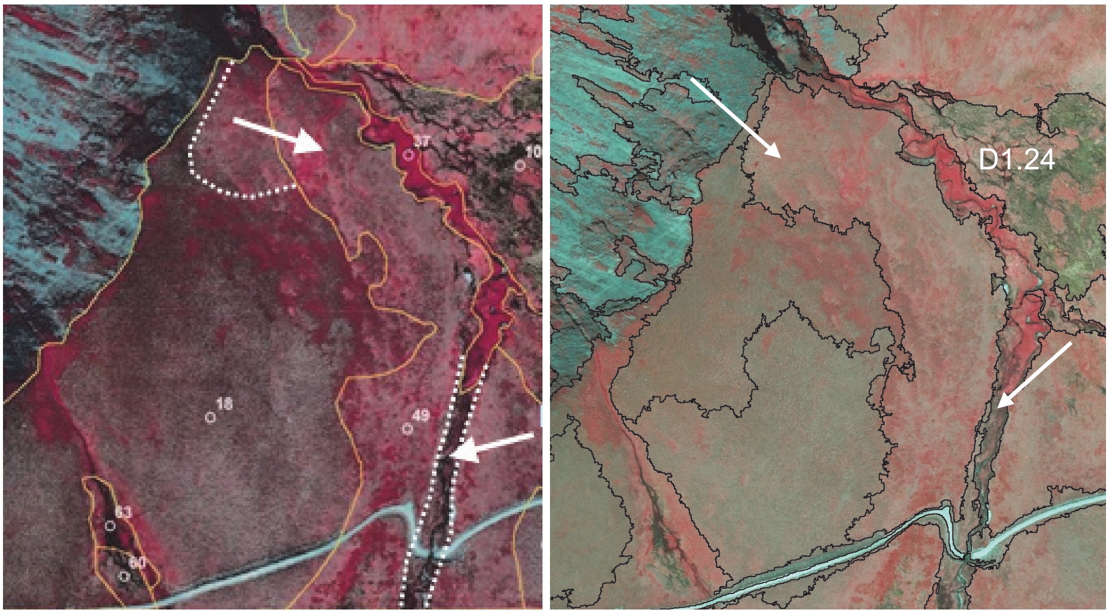


Figure 17. Validation 1 (left) suggested boundary changes (dashed lines and white arrows) which were recognised in the Environment Systems segmentation (right) (white arrows). Polygon dominated by bare peat marked D1.24.

4.4.1 Recommendations

Using automated segments as an alternative to manual delineation of polygons could potentially:
a) provide a more consistent split between habitats and
b) speed up the delineation process significantly (if segmentation is created at a suitable level of detail).

- It is therefore recommended that automated image segmentation should be explored further. It may be that there is a suitable segmentation which could delineate polygons for entire areas (covering all habitats) or that segmentation could be used for selected habitats for which it works well (e.g. scree habitats).

- Should a segmentation approach be adopted and found to give extra value, then bare peat should be mapped and classified in its own right.

- Image segmentation, whether it is done on satellite or aerial imagery, is often followed by a rule based classification. Trialling the value of a rule based classification with subsequent validation or infilling of gaps using aerial imagery interpretation or on-site visits is recommended. This topic is not within the remit of this report and is therefore not discussed further.

5. SUMMARY CONCLUSIONS AND RECOMMENDATIONS

Building a methodology for the identification of all upland habitats using stereo imagery will take time. Mapping all upland habitats using stereo imagery will also take time although it is envisaged that it will be significantly more efficient than field surveying the same area.

With the likelihood of working within tight resources it is recommended that habitats are identified using the most efficient methods available. This means that any data and any method could be used as long as it produces results that fulfil the mapping requirements. This strategy is likely to demand a hierarchical data and method approach where the fastest, more automated, mapping methods are used first and more hands-on approaches including stereo aerial imagery interpretation are used subsequently for habitats that are not captured well enough using the faster methods. Then, site visits or new data capture, for example using unmanned aerial vehicles (UAVs), may be required. An overview of this multi-data and multi-method approach is given in Figure 18.

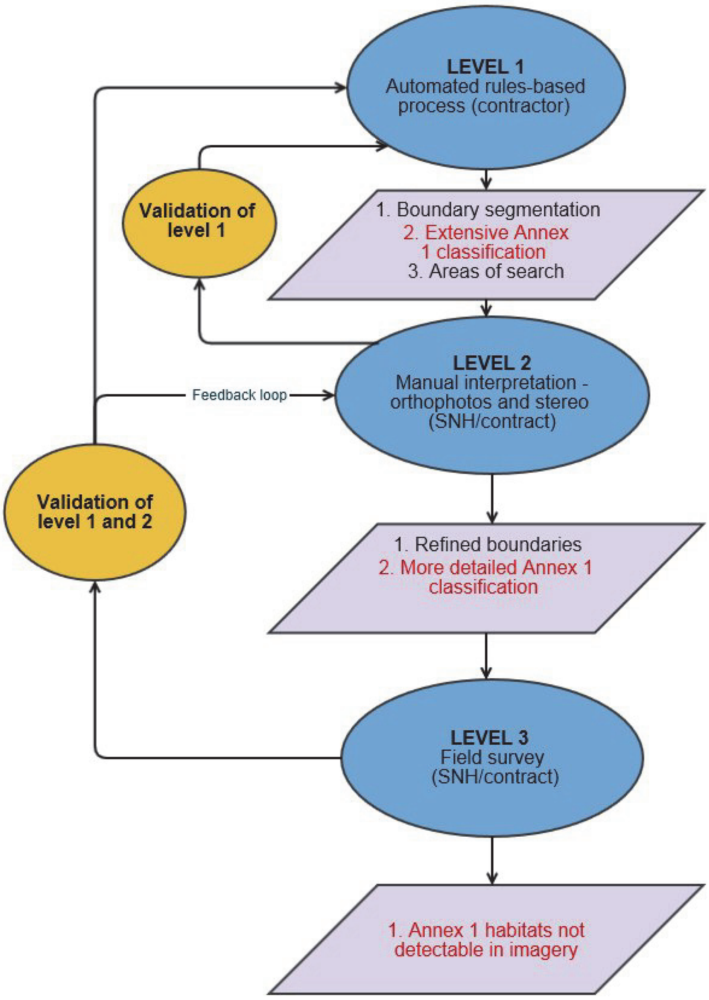


Figure 18. Flow chart giving an example of how the multi-data and multi-method approach could work (Blake, 2014).

This multi-data, multi-method approach demands a good understanding of remote sensing methods as well as habitat expertise and it is strongly recommended that an operational team has, or is trained in, both. It is envisaged that stereo imagery interpretation will have an important role to play in this approach, especially for small, fragmentary habitats or for habitats where detail is needed for identification. It can also be used to check and, where necessary, correct (increase the accuracy of) polygons classified using more automated methods.

Overall, the processes and outputs of this small trial, conducted with limited resources, have illustrated the considerable potential that exists for the use of stereo aerial imagery in mapping Annex 1 and EUNIS habitats in the trial area and beyond. They have also shown the importance of establishing and enforcing mapping rules and clarity over habitat classification, in order to create a consistent map, to assess accuracy, and ensure repeatability. Further development, in a pilot study investigating the full potential of this and other habitat mapping approaches, is encouraged.

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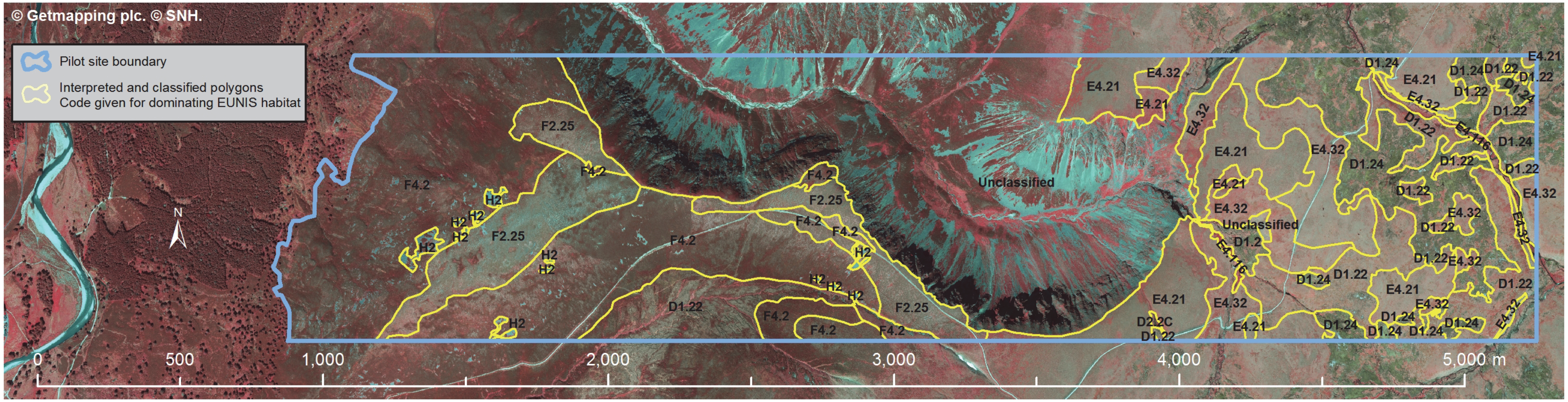
ANNEX 1: TARGET HABITATS FOR GLENFESHIE TRIAL BASED ON EUNIS CORRESPONDENCE TABLE

Based on Strachan (2015)

EUNIS ID[1]	EUNIS	EUNIS description	Annex I	Annex I description	NVC Correspondence (* part only)	NVC likely on site (* part only)
40102	D1.2	Blanket bogs	H7130	Blanket bog		
4010202	D1.22	Montane blanket bogs, *Calluna* and *Eriophorum vaginatum*	H7130	Blanket bog	M1* M2* M3* M15* M19* M20*	M19
4010204	D1.24	Wet bare peat and peat haggs on blanket bogs	H7130	Blanket bog	In association with M1* M2* M3* M15* M17 M18* M19* M20* M25*	In association with M19
4020202	D2.22	[*Carex nigra*], [*Carex canescens*], [*Carex echinata*] fens	NONE	NONE	M6 M7	
40202003	D2.2C	Soft water spring mires	NONE	NONE	M31-33 M35-36	M32
4020399	D2.3€	Transition mires and quaking bogs (Annex I)	H7140	Transitional mires and quaking bogs	M4* M5* M8 M9* M29* S27	?
404010599	D4.15€	Alkaline fens	H7230	Alkaline fens	M10* M11* (without montane species) M9*	M10* M11* (without montane species)
4040299	D4.24€	Alpine pioneer formations of the *Caricion bicoloris-atrofuscae*	H7240	Alpine pioneer formations of the *Caricion bicoloris-atrofuscae**	M10* M11* M12 M34	M10* M11* (with montane species)
5010206	E1.26	Sub-Atlantic semi-dry calcareous grassland	H6210	Semi-natural dry grasslands and scrubland facies: on calcareous substrates (Festuco-Brometalia)	CG2 CG7 CG10*	CG10*
50107029	E1.72#	Species-rich *Nardus* grassland, on siliceous substrates in mountain areas	H6230	Species-rich *Nardus* grassland, on siliceous substrates in mountain areas (and submountain areas in continental Europe)	CG10* CG11 U4* U5c	CG10*
504010106	E4.116	Boreo-alpine [*Deschampsia*]-[*Anthoxanthum*] communities	NONE	NONE	U13a	U13a
504030299	E4.32€	Siliceous alpine and boreal grasslands	H6150	Siliceous alpine and boreal grasslands	U7 U8 U9 U10 U11 U12 U14	U7 U9 U10
5040201	E4.21	Oroboreal [*Carex bigelowii*]-[*Racomitrium*] moss-heaths	H6150	Siliceous alpine and boreal grasslands	U9 U10	U9 U10
5040302	E4.32	Oroboreal acidocline grassland	H6150	Siliceous alpine and boreal grasslands	U7 U8	U7
5050509	E5.59	Oro-boreal tall-herb communities	H6430	Hydrophilous tall herb fringe communities	U17	U17
60201	F2.1	Subarctic and alpine dwarf willow scrub	Incl. H4080	Incl. Sub-arctic *Salix* spp. scrub	Includes W20 (H4080)	Includes W20 (H4080)
6020205	F2.25	Boreo-alpine and arctic heaths	H4060	Alpine and Boreal heaths	H13 H14 H15 H17 H18* H19 H20 H22 (montane forms of H10,12,16,21 could be assigned here)	H13 H18* H19 H22 (montane forms of H10,12,16?)
60402	F4.2	Dry heaths	H4030	European dry heaths	H7* H8* H9 H10* H12* H16* H18* H21*	H10 H12 H16 H18* ?H21
802030199	H2.31€	Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani*)	H8110	Siliceous scree of the montane to snow levels (*Androsacetalia alpinae* and *Galeopsietalia ladani*)	U18* U21* and other non-NVC vegetation	non-NVC vegetation
802	H2	Siliceous and basic screes	H81	Either H8110 or H8120		
80204	H2.4	Temperate-montane calcareous and ultra-basic screes	H8120	Calcareous and calcshist screes	OV38* OV40* other	other non-NVC
803019	H3.1#	Siliceous rocky slopes with chasmophytic vegetation	H8220	Siliceous rock slopes with chasmophytic vegetation	other non-NVC	other non-NVC
8030205	H3.25	Alpine and sub-mediterranean chasmophyte communities	H8210	Calcareous rocky slopes with chasmophytic vegetation	OV39* OV40* and other non-NVC	other non-NVC
0	UNCLASS	Unclassified	UNCLASS	Unclassified	N/A	N/A

[1] A numerical ID for each EUNIS habitat class, created for the project, allowing it to be used in a GIS with more ease as certain types of datasets and geodatabase settings only accept integer codes

ANNEX 2: MAP SHOWING STEREO INFRA-RED AERIAL IMAGERY INTERPRETED BOUNDARIES AND EUNIS CLASSIFICATION



This is an enlarged version of Figure 15 in the main report.

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