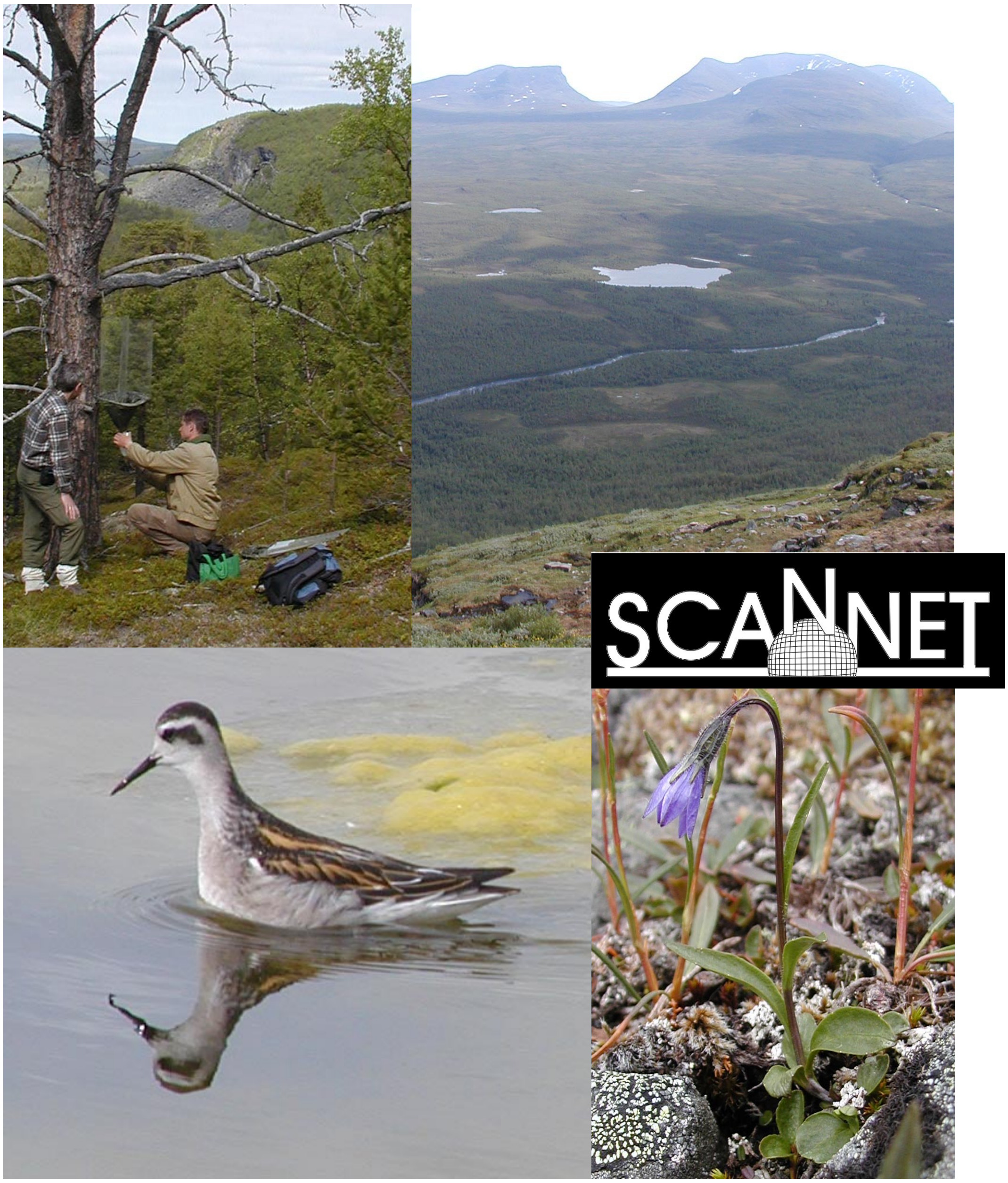
Spatial and temporal variation in biodiversity in the European North



SCANNET-Scandinavian/North European
Network of Terrestrial Field Bases
Work Package 6 – Final report

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1. Preface

This report escorts annotated check-lists of selected taxonomic groups and a biodiversity bibliography of North-Western Europe (+ Greenland) which are stored on the SCANNET data server and are accessible through the SCANNET website at: http://www.scannet.nu. Background information about the biodiversity of various taxonomic groups and about the history of research on them in different SCANNET nodal areas are summarised. Major gaps and weaknesses (as well as the strengths) in the North European biodiversity knowledge are identified. There are several challenges in monitoring the biodiversity in the harsh northern areas, which are often remote and have large territories. The feasibility and methods of comparable and standardised biodiversity monitoring schemes for the northernmost Europe are discussed.

Together this report, the check-lists, and the bibliography form the main output of SCANNET work package 6, Standardisation of protocols: Spatial and temporal variation of biodiversity. The results have been compiled from many sources, the most important being the detailed information from the field bases in the SCANNET network.

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Cover photos (all © Seppo Neuvonen):

Top-Left:	Sampling insects at Scots pine forest line near Kevo subarctic Research Station.
Top-Right:	Lapporten viewed from Njulla near Abisko Scientific Research Station.
Bottom-Left:	Red-necked Phalarope (*Phalaropus lobatus*) is one of the northern waders breeding in the SCANNET region.
Bottom-Right:	The distribution of *Campanula uniflora* is confined to Alpine and Arctic habitats.

Seppo Neuvonen (2004) Spatial and temporal variation in biodiversity in the European North. SCANNET – Scandinavian/North European Network of Terrestrial Field Bases. Work Package 6 – Final report.

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3. Abstract

Despite the general decrease in species richness towards the Arctic, the Fauna and Flora of the SCANNET region shows unique Northern/Arctic features, which make the area very interesting and important for the monitoring of biodiversity. This report gives background information about the biodiversity knowledge of selected taxonomic groups in different parts of the SCANNET region. Taxa like birds, mammals, some better known aquatic and terrestrial invertebrate groups, and vascular plants, are known sufficiently well in the region and specifically around SCANNET field bases, so that a representative portfolio for biodiversity surveys and monitoring could be formed. Concluding, SCANNET provides an excellent platform and possibility for biodiversity research and monitoring in the European North: a representative network of sites with high diversity of northern habitats and with already accumulated knowledge about many taxonomic groups suitable for monitoring and presenting interesting research questions.

4. Biodiversity and Biodiversity Knowledge in the SCANNET Region

4.1. General Introduction

Biodiversity is a concept/topic dealing with the biota as a whole and it implicitely deals also with conservation issues, i.e. it is not value-neutral (cf. Pielou 1995). It is also common to distinguish different hierarchical levels when studying/discussing biodiversity: (1) ecosystem/habitat diversity; (2) species level diversity (species richness); (3) intra-specific (genetic) diversity/variation.

The aim of this work package [SCANNET WP6: Standardisation of protocols: spatial and temporal variation of biodiversity] has been to compile and present regional and site specific information on biodiversity. Baseline information on habitat and species diversity is assessed and presented at different spatial levels from sites to natural historic provinces. The SCANNET field bases have a combined knowledge and expertise in biodiversity research and monitoring far exceeding that of any single station. The purpose of this report and associated material available in the Internet (http://www.scannet.nu) is to distribute this knowledge, expertise and good practises learnt during the first SCANNET period over the whole area and to different user communities. Annotated check-list for various taxonomic groups at the SCANNET sites are presented, together with discussion of the problems with compiling such lists and in biodiversity monitoring in general. Compilation of bibliographies and check-lists for different areas (e.g., SCANNET nodal areas) are processes during which both temporal and spatial variation in the availability of biodiversity information (specifically, at the species level) become apparent, and the gaps in knowledge are surfaced.

When collating and assessing of species level biodiversity information in the SCANNET region, one should remember that there are huge differences in surveying and monitoring biodiversity of different groups of organisms. Some taxonomic groups are relatively “easy”, like birds and vascular plants – it is possible to observe and identify the species in the field (of course, considerable expertise is normally required). The second level could be named as the “normal case” (most insect groups, mosses, lichens, etc) – species identification is more difficult [although identification guide books are available (there are also generally less specialists/experts capable of identification) the specimens sampled may often require microscopic examination] and special methods can be necessary for the collection of samples. Furthermore, the sorting and identification of large samples (thousands of individuals) is very time consuming, which means that often the data will often be available only several years after the sampling. At the third level, "difficult taxa" (e.g., sawflies, ichneumonids, many soil organisms), some additional difficulties emerge – taxonomic problems have not yet been resolved, species numbers can be large even in northern areas, all species have not yet been described, identification guides are not available, there are really few experts capable of identification, etc.

One problem associated with the compilation of biodiversity information in the SCANNET region is that the samples collected at the field bases or in their surroundings are not generally stored at the field bases but in botanical/zoological/entomological museums or in private collections. Specifically, there are generally no comprehensive insect collections at the SCANNET field bases. This means that the museum samples and other biodiversity information from these northern/remote areas may often be stored far away from the region. Unfortunately, there seems to be sometimes poor information flow from the amateurs, researchers, or museums back to the areas from where the organisms have been collected, e.g. to SCANNET field bases.

Furthermore, Biodiversity literature dealing with the SCANNET region is published in many languages (English, Swedish, Norwegian, Danish, Faeroese, Icelandic, Finnish, German; although Kalaallisut (East-Inuit; Greenlandic) and several Sámi languages are also spoken in the region, not much biodiversity literature has been published in these languages) and often in journals or reports with limited distribution. An additional problem for compiling biodiversity knowledge is that there are many stakeholders involved. For example, Cairngoorms Partnership (2000; Catalogue of Cairngorms Moorland Data) in Scotland lists over 25 organisations involved in different biodiversity surveys. Another example comes from the Kilpisjärvi area in north-westernmost Finland. In addition to Kilpisjärvi Biological Station, essential biodiversity information for the Kilpisjärvi – NW-Enontekiö area has to be searched at least from the following sources: Kilpisjärvi and Kolari field stations of the Finnish Forest Research Institute (FFRI), Botanical and Zoological Museums in the Universities of Helsinki and Oulu, Metsähallitus (= Finnish Forest and Park Service), Finnish Environment Institute, Lapland Regional Environment Centre, Finnish Game and Fisheries Research Institute, and possibly also from Ornithological and Entomological Societies and from private persons.

Despite the general decrease in species richness towards the Arctic (and especially Arctic Islands), the Fauna and Flora of the SCANNET region shows unique features ('Northern/Arctic' character; high level of intraspecific variation; high diversity of adaptations to extreme environmental conditions; see e.g.., CAFF 2001), which make the area very interesting and important for the monitoring of biodiversity.

The North Atlantic – European Arctic area (= "SCANNET region") shows considerable variation both in environmental harshness and in spatial isolation of the sites (Fig. 1). Both are important constraints for species richness. However, some taxonomic groups are well-adapted and relative species rich in northern, harsh environments (e.g., willows, sawflies, stoneflies, waders, salmonids), and these groups could be considered as "flagship taxa" for the area in general. Isolation not only reduces the species richness, but it has other effects, which are important in the biodiversity context. Isolated and small populations have possibly enhanced rates of evolution/speciation, which means that the importance of intra-specific variation in the area should be highlighted. Spatial isolation has a number of consequences for the dynamics of biodiversity under environmental changes (important when monitoring biodiversity is the issue):

- (small) isolated populations may be especially vulnerable to rapidly changing environmental conditions;
- spatial isolation slows down the immigration rate of new species even if the environmental conditions become favourable for them → if the potential newcomers are superior competitors to the 'original species', this may be beneficial for the original Fauna/Flora (its replacement will be delayed);
- in some SCANNET Areas (e.g., Iceland) introduced alien species may pose a serious threat to 'natural biodiversity'.

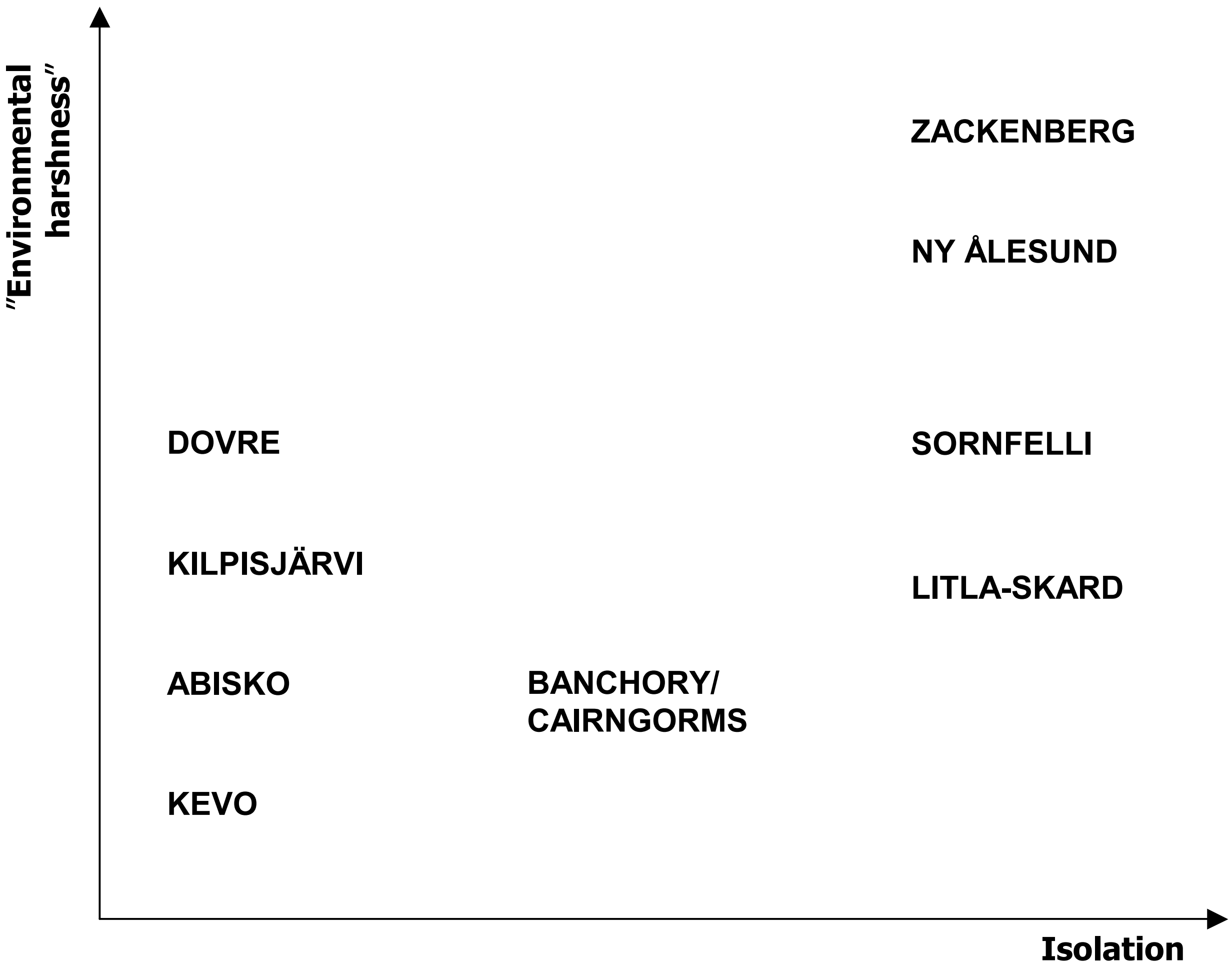

Fig. 1. The SCANNET nodal sites/areas are arranged along the axes of spatial isolation (mainland vs. islands) and environmental harshness (generally increases with latitude and altitude). This figure should be kept in mind as a background when looking at the patterns of species richness of various taxonomic groups in the SCANNET region.

Given the difficulties in biodiversity monitoring of many taxa discussed above, a question arises whether some taxonomic groups (preferably towards the "easy" end of the continuum described above) could be used as ("rapid" and "cheap") indicators of biodiversity in both regional biodiversity surveys and in monitoring temporal changes in biodiversity. Unfortunately, there is evidence that probably such biodiversity indicator taxa/groups do not exist – different taxonomic groups seem (when compared) to show different patterns of biodiversity variation (Prendergast & Eversham 1997). Species turnover (replacement) from area to area along the environmental gradients (whether natural of anthropogenic) differs among the taxonomic groups (Harrison et al 1992, Lawton et al. 1998). This means that no single group of organisms is a good surrogate for a more comprehensive study of biodiversity. At least, a reasonably comprehensive "portfolio" of representative (of different life forms, habitat types, ecosystem services, etc) taxonomic groups should be included in a biodiversity survey or monitoring programme, if an all-taxa-survey is not possible. This report focuses on some good candidate taxa for such a portfolio, and presents information about the biodiversity of these groups in SCANNET nodal areas.

Promising taxonomic/ecological groups for collection of standardised information in the SCANNET region should:
- represent a comprehensive variety of northern habitats and ecological functions (ecosystem services) in these;
- to be responsive to a variety of environmental changes (both 'natural' and anthropogenic);
- to have some degree of specificity to particular drivers of biodiversity change;
- to be sufficiently species rich in northern areas to make it feasible to statistically analyse changes in biodiversity;

Furthermore:
- quantitative sampling methods at a feasible spatial scale (group specific) should be available;
- solid ecological knowledge about the group in the region should be available;
- taxonomy of the group should be sufficiently well known.

As a first attempt to delineate a set of candidate taxa for biodiversity surveys/monitoring in the SCANNET region, some smaller taxa within the following larger groups are treated below in more detail: Vertebrates (especially Birds and Mammals; Section 6), Invertebrates (both Aquatic (Odonata, Plecoptera, etc) and Terrestrial (spiders, carabid beetles, butterflies); Section 7), and Plants (Section 9). The focus is in species level diversity (species richness) and in species/groups characteristic for northern areas. However, intra-specific variation is an important component of biodiversity in the North Atlantic - Arctic area because of prominent environmental variability (both spatial and temporal) and isolation in the area. Intra-specific variation is also a valuable resource for future use by humans. Furthermore, it provides the northern/arctic organisms possibilities to adapt to rapid environmental changes. In the following treatment intra-specific variation is highlighted where appropriate within the different taxonomic groups.

To give a rough idea of the numbers of species present in different taxonomic groups in or around the SCANNET nodes at the less harsh and less isolated edge of the area, reference is made to the list of all organisms reported to have been found in Inari Lapland (InL). The list is now available on Internet at http://www.utu.fi/erill/kevo/eliot/. The list was compiled by Lasse Iso-Iivari (Kevo Subarctic Research Institute, Univ. of Turku). The area is a natural historic province in northernmost Finland (Inari and Utsjoki municipalities; total area 22'705 km^2, situated between 68^o and 70^o N).

Table 1. *The numbers of species in different Phyla in the Inari Lapland area are shown in the following table. Highlighting denotes taxa with 10-99 species, 100-999 species, and ≥ 1000 species.*

Phylum	
Cyanobacteria	63
Rhizopoda	4
Conjugaphyta	219
Cryptophyta	1
Euglenophyta	2
Haptophyta	1
Dinoflagellata	10
Chrysophyta	32
Ciliophora	5
Bacillariophyta	370
Chlorophycota	55
Xanthophyta	2
Myxomycota	33
Oomycota	1
Ascomycotina	859
Basidiomycotina	823
Bryophyta	345

Phylum	
Pteridophyta	41
Magnoliophyta	598
Porifera	1
Rotifera	26
Cephalorhyncha	2
Platyhelminthes	1
Mollusca	26
Annelida	10
Chelicerata	311
Crustacea	41
Uniramia	3016
Chordata	319

Summarising, a total of over 7200 species can occur in some of these northern areas. Given the geographical variation in the species composition between different SCANNET nodal areas (see e.g., Marusik & Koponen 2000), it is safe to assume that the total species richness in the SCANNET region is of the order of 10'000 species. In Inari Lapland (the area surrounding Kevo) Uniramia (includes Insects) is clearly the most species rich Phylum with over 3000 species (and it should be noted that many insect groups are still relatively poorly known). Other species rich taxa are e.g., vascular plants (Pteridophyta + Magnoliophyta; >600 spp.), Ascomycotina ('sac fungi', including e.g., yeasts & lichens; >850 spp.), Basidiomycotina (mushrooms, rusts, etc; >800 spp.), Bryophyta (mosses; >300 spp.), Chelicerata (including spiders and oribatid mites; >300 spp.), and Chordata (vertebrates; >300 spp.).

It has become obvious that the biodiversity in the SCANNET region is responsive not only to climate change but to changing land-use pressures as well, also to those occurring outside northern Europe. The threats to biodiversity are variable among the different focal sites, as are the potential rates at which climate change impacts on biodiversity are expressed. The monitoring of changes in biodiversity in the SCANNET region is complicated because of the cumulative nature of the observations and species lists (and accompanied difficulties in verifying the possible disappearance of species in large and remote areas) and changes in observation efficiency (Fig. 2; see also Fig. 4 in Section 7.1).

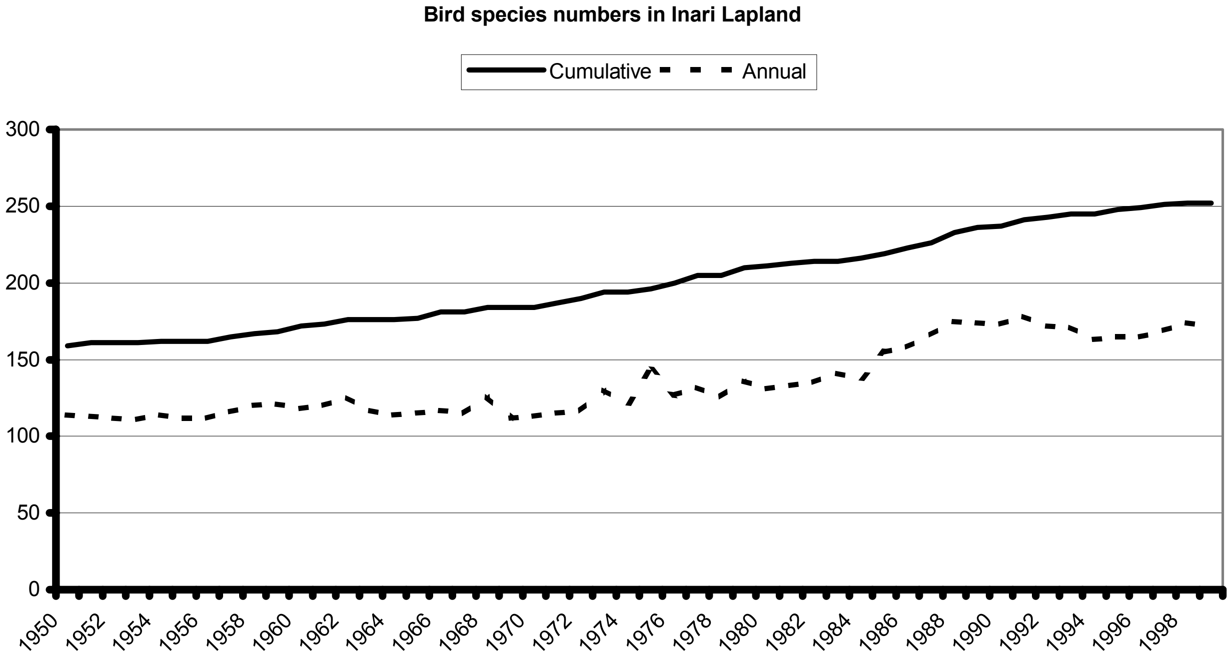

Fig. 2. The increase in the number of bird species observed (both cumulatively and annually) in Inari Lapland (northernmost Finland) from 1950 to 1999 is partly due to increased observation efficiency and only partly due to real changes in the Fauna. During this period the number of 'breeding bird species' has increased from 106 to 128 (2 bird species have probably been extinct), but whether the change is real has to be worked out species by species (see below: Section 6.6). The variation in the number of annually explained species is partly explainable by the two national Bird Atlases in Finland (in mid-1970'ies and late-1980'ies) and by the movement of some enthusiastic bird watchers into the area during 1980'ies.

In the following the general features of biodiversity for different taxonomic groups in the SCANNET region are summarized, focusing on species level biodiversity, but dealing also with intra-specific diversity where appropriate. Furthermore, the feasibility of biodiversity monitoring of each taxonomic group and the appropriate methods are discussed. Also the various threats to biodiversity (loss of habitat, climate change, land use changes, alien/invasive species, etc), which vary between different SCANNET nodal areas, are shortly discussed for different taxonomic groups. As SCANNET is the Scandinavian – North-Europan Network of Terrestrial Field Bases, we restrict our treatment to the biodiversity of terrestrial and fresh water habitats and species.

References:
- CAFF (Conservation of Arctic Flora and Fauna) (2001) Arctic Flora and Fauna: Status and Conservation. Edita, Helsinki. 272 pp.
- Harrison, S., Ross, S. J. & Lawton, J. H. (1992) Beta diversity on geographic gradients in Britain. J. Anim. Ecol. 61**:** 151–158.
- Lawton, J.H., Bignell, D.E., Bolton, B., Bloemers, G. F., Eggleton, P., Hammond, P.M. Hodda, M., Holt, R. D., Larsenk, T.B., Mawdsley, N.A., Stork, N.E., Srivastava, D.S. & Watt, A.D. (1998) Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. Nature 391: 72-76.
- Marusik, Y.M. & Koponen, S. (2000) Circumpolar diversity of spiders: implications for research, conservation and management. Ann. Zool. Fennici 37: 265-269.
- Pielou, E.C. (1995) Biodiversity versus old-style diversity: measuring biodiversity for conservation. Pp. 5- 17 in Boyle, J.B. & Boontawee, B. (eds): Measuring and Monitoring Biodiversity in Tropical and Temperate Forests. Center for International Forestry Research (CIFOR), Bogor, Indonesia.
- Prendergast, J. R. & Eversham, B. C. (1997) Species richness covariance in higher taxa: empirical tests of the biodiversity indicator concept. Ecography 20: 210–216.

4.2. SCANNET Biodiversity Bibliography

One of the methods used to assess the biodiversity knowledge (and to make it better available for potential users) and identify gaps in the knowledge at different field bases of the network was starting to compile an annotated SCANNET Biodiversity Bibliography (SBB). In addition to the bibliographic information the SBB contains keywords to facilitate searching and sorting of the information. It was soon realized that the bibliographies of different field bases available at the SCANNET www-pages were only partially sufficient for the task. The bibliographies from Abisko, Kilpisjärvi, and Kevo contained a lot of relevant and useful references. There were no references in the bibliography of Sornfelli Meteorological Station (Faroe Islands), and there was no bibliography available for Dovre (Central Norway). There were only two references in the bibliography of Litla-Skard (Western Iceland), and due to the relatively recent starts of the Zackenberg Research Station (NE Greenland) and Cairngorms Environmental Change Network (ECN) site (Scotland) there were only few relevant references from these stations. Consequently, more relevant (topic: biodiversity) references were searched for Greenland, Svalbard, Iceland, and Faroe Islands. There were not so many references specifically from western Iceland but northern Iceland (Myvatn area) was better represented. The available time did not allow comprehensive biodiversity literature searches for Cairngorms/Scotland nor for Dovre areas. Consequently, SBB is by no means inclusive...the citations listed it represent only a small subset of the relevant literature!

Table 2 shows the number of references in SBB divided with respect to different nodal areas and time periods. It is clearly evident that there are great differences between different SCANNET nodal areas both in the accumulated total volume of research/publications and in its temporal distribution. Abisko area has had intensive faunistic and floristic research for already over 100 years while more intensive research in northernmost Finland (Kilpisjärvi and Kevo areas) started only in 1950-1960'ies. It should be noted that the actual field studies have generally been done 1-10 years before the publication. The biodiversity publications from the northernmost (and most isolated) SCANNET areas have increased in volume only during the last decades. It is obvious that there has been intensive faunistic and floristic research for a long time both in Cairngorms/Scotland areas and in the Dovre area. Consequently, a thorough search of biodiversity related publications for these areas would increase the respective numbers in SBB by an order of magnitude.

Table 2. Temporal distribution [by century (<1900) or by decade (>1900)] of the references from different nodal areas in the SCANNET Biodiversity Bibliography.

	1700-c	1800-c	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
Greenland/Zackenberg	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**3**	**156**	**44**
Iceland/(Litla-Skard)	**0**	**1**	**1**	**0**	**3**	**1**	**3**	**5**	**7**	**37**	**21**	**72**	**35**
Faroe Islands	**0**	**2**	**6**	**0**	**4**	**3**	**0**	**2**	**3**	**6**	**14**	**27**	**21**
Ny-Ålesund	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**6**	**7**	**16**	**76**	**19**
Cairngorms/Scotland	0	0	0	0	0	0	0	0	0	1	7	13	2
Dovre	0	0	0	0	0	0	1	0	0	6	8	8	1
Abisko	**4**	**10**	**29**	**71**	**103**	**119**	**133**	**163**	**97**	**99**	**72**	**60**	**4**
Kilpisjärvi	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**3**	**21**	**53**	**30**	**3**
Kevo	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**14**	**90**	**65**	**93**	**36**	**5**

The SCANNET Biodiversity Bibliography has now over 2000 references. Increasing the coverage of relevant literature, especially for Cairngorms/Scotland and Dovre/Norway areas, remains as a task for the future. A useful source of information has been compiled by Östbye (1997) – a bibliography of the Finse area which is another mountain area in Norway, not far from Dovre.

References:
- Östbye, E. (1997) The bibliography of the Finse Area 1781-1996. Reports from the High Mountain Ecology Research Station, Finse, Norway. Universities of Bergen and Oslo.

5. Habitat Diversity in the SCANNET Region

5.1. Introduction – Habitats in the SCANNET Region

The landscapes surrounding each of the SCANNET nodes show considerable variety of habitats. Obviously, there is a general "northern aspect" in the habitats to be found in this region. The terrestrial habitats in the individual SCANNET sites range from coniferous forests to Alpine/Arctic vegetation (e.g, Abisko, Cairngorms, Kevo) or from Alpine/Arctic vegetation to polar desert and glaciers (e.g., Zackenberg, Ny-Ålesund). Furthermore, proximity to sea characterizes three of the nine SCANNET sites. The compilation in Table 3. shows the occurrence of major habitat types around the individual SCANNET sites. Furthermore, it shows the occurrence of some more specific habitats (see below) in the same areas. In general, it can be concluded that northern freshwater and terrestrial habitats are well represented in the surroundings of SCANNET sites.

Table 3. The occurrence of major habitat categories in the surroundings of different SCANNET field bases. The three last columns show the occurrence of some specific northern habitats.

MAJOR 'HABITATS' AROUND SCANNET SITES:							Some specific habitats near SCANNET sites		
	Within 16 km radius from the focal site:								
	sea	freshwater		terrestrial					
		lakes	rivers/ brooks	forests	alp./ arctic	glaciers	Palsa mires	Snow bed vegetation	Tree line ecotones
Zackenberg	+	+	+	-	+++	++	-	+	-
Litla-Skard	-	++	+	d	+	-	(+)[1]	+	+
Sornfelli	+	+	+	-	++	-	-	+	-
Ny-Ålesund	+	+	+	-	+++	+	(+)[2]	+	-
Cairngorms/Banchory	-	+	+	c&d	+	-	-	+	+
Dovrefjell	-	+	+	d	++	-	+	+	+
Abisko	-	++	+	c&d	++	(+)	+	+	+
Kilpisjärvi	-	++	+	d	++	-	+	+	+
Kevo	-	++	+	c&d	+	-	+	+	+

[1]: Palsa mires occur in central Iceland (Friedman et al. 1971).
[2]: "Palsa like mounds" have been reported from Svalbard (Åkerman 1982, 2003).

5.2. Vegetation mapping

A general difficulty with vegetation maps in larger geographical contexts is that vegetation maps are almost always produced for quite small areas and using a large variety of vegetation classifications, map scales, and national mapping traditions. A notable exception is the Circumpolar Arctic Vegetation Map (CAVM) recently published by an international team after 11 years of work. CAVM is the first vegetation map of an entire global biome being reasonably detailed (1:7,500,000; 1 km * 1 km pixel size; 4 types of Barrens, 4 types of Graminoid Tundras, 2 types of Prostrate-shrub and 2 types of Erect-shrub Tundras, and 3 types of Wetlands) and using common legends. The CAVM can be downloaded at: http://www.geobotany.uaf.edu/cavm/.

The CAVM covers the region north of the Arctic tree line. With respect to SCANNET region it's a pity that only two of the field bases (Zackenberg & Ny-Ålesund) are within the area included in the CAVM project. On the other hand, many practical applications and research projects would need vegetation maps with higher resolution and more detailed vegetation classification. Furthermore, the vegetation types at many SCANNET nodal areas have been under more or less intense human influence over many centuries [being especially pronounced in Scotland (Banchory/Cairngorms) and Iceland (Litla-Skard)], and the large climatic variability over the area (both North-South and oceanity-continentality gradients) leads to the fact that not many same vegetation types (at the more detailed level of classification) are shared between the different SCANNET nodal areas.

Table 4. Vegetation maps available from different SCANNET nodal areas.

SCANNET nodal area	Area mapped	Scale	Size of the Area	# of veg. types	References
Zackenberg	**	ca. 1:25'000	ca. 19 km^2	12	**1**
Littla Skard	Iceland	1:40'000	..		**2**
Sornfelli	-				
Ny Ålesund	Svalbard	?	..	4	**3**
	Brøgger-halvøya	1:10'000	ca. 5 km^2	19/8	**4**
Cairngorms	Cairngorms	1:370'000	Ca. 7'000 km^2	15	**5**
Dovre	Mainland Norway		..		**6**
Abisko	Swedish Fjell areas	1:100'000	..	ca. 30	**7**
	Latnjajaure catchment				**8**
Kilpisjärvi	NW Enontekiö	1:150'000		10	**9**
	Malla Strict Nature Reserve	ca. 1:25'000	ca. 30 km^2	ca.20	**10**
	Pallas-Ounastunturit Natonal Park	..	ca. 509 km^2	ca. 50	**11**
Kevo	Kevo Strict Nature Reserve	1:50'000	363 km^2	ca. 30	**12**
	Inari Lapland	1:200'000	ca. 25'000 km^2	7	**13**
	Vuoskujärvi Integrated monitoring area	1:11'765	1.8 km^2	7 (16)	**14**

1: Bay (1998); see also Mosbech & Hansen (1994); **2:** Gróðurkort af Íslandi.. ;
3: http://miljo.npolar.no/temakart/images/maps/SvalbardVegetationMap.gif
4: Brattbakk (1981), Spjelkavik (1995), Nilsen et al. (1999); **5:** Cairngorms Partnership (1998);
6: Moen (1999); **7:** Vegetationskarta .. nr. 2; **8:** Liess (1999); **9:** Sihvo et al. (2000);
10: Kauhanen et al. (2003), Kauhanen & Mattson (2004); **11:** Eeronheimo et al. (1992);
12: Heikkinen & Kalliola (1989); **13:** Seppälä & Rastas (1980); **14:** Tuominen et al. (2001).

Separate vegetation maps have been produced for areas surrounding or close to most SCANNET nodes as shown in Table 4. It should be noted that vegetation is quite dynamic in the area due to changes in climate, pollution (Sulphur & Nitrogen deposition), and/or in grazing pressure (e.g., Erschbamer et al. 2003, Virtanen et al 2003). There is also a voluminous literature on the vegetation types in the SCANNET region; some of these references are listed below (e.g, Ahti et al. 1968, Carlsson et al. 1999, Fremstad 1997, Eurola et al. 2003, Haapasaari 1988, Kyllönen 1988, Oksanen & Virtanen 1995, Virtanen 1996, Virtanen & Eurola 1997) and more can be found in the SCANNET Biodiversity Bibliography.

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See also: http://miljo.npolar.no/temakart/images/maps/SvalbardVegetationMap.gif (Svalbard Vegetation Map)
http://miljo.npolar.no/temakart/pages/homeE.asp?letter=S (Norwegian Polar Institutes Thematic Maps – Svalbard)
http://www.ntnu.no/vmuseet/nathist/boeker/vegatl_e.html (National Vegetation Atlas of Norway)

5.3. Some specific habitats – vegetation types in the SCANNET Region

5.3.1. Palsa mires and snow-bed vegetation

Palsa mires are a specific type of mire geomorphology and vegetation in the subarctic zone: small or medium sized (0.5 – 10 m in height) peat hummocks with permafrost core (palsas) rise out of the wetter mire surface (Fig. 3). They are especially well represented in the area of discontinuous permafrost, i.e. in most of the continental SCANNET nodal areas, i.e. in the surroundings of Abisko, Kevo, and Kilpisjärvi (see e.g. the map in Seppälä 1988). A somewhat separate and small occurrence of palsas is in the Dovre area (Sollid & Sørbel 1998) and there are palsa mires also in Iceland (Friedman et al. 1971). Climatically, in addition to low air temperature, the thickness of snow cover is critical for the decelopment and occurrence of palsas (Seppälä 1988).

The development of palsas is a cyclic process (described in detail by Seppälä 1998; only a short summary follows): it starts when the snow cover over a mire surface is locally so thin that frost during the winter penetrates deep enough so that the frozen peat does not melt during the following summer(s). The surface of the peat layer is raised by frost processes, which leads to a positive feedback loop where frost penetrates still deeper during successive winters. In later stages of palsa development the peat hummock starts to degrade and old palsas are partially destroyed by thermokarst (Fig. 3 left). New palsas may later emerge after peat formation and when/if the conditions for their formation are suitable (see above). Typically a palsa mire is a mixture of palsas at different stages of the cycle.

Fig. 3. A partly collapsed palsa in northernmost Finland (left) and experiments (CONGAS project) addressing the effects of climate change on methane emissions in a palsa mire near Kevo (right).

A recent analysis in Western Utsjoki near Kevo (3370 km^2 study area) revealed that 1 km^2 squares with only thermokarst (remains of earlier palsas) were over twice as abundant than squares with current palsas, suggesting that the palsas are disappearing at an alarming rate (Luoto & Seppälä 2003). On the basis of recent (and predicted future) increases in temperatures and precipitation it has been predicted that most of these sensitive formations can disappear (melt) within a few decades, especially near the margins of their current distribution (Sollid & Sørbel 1998). A national palsa peatland monitoring project for Norway has been proposed recently (Hofgaard et al. 2003). Unfortunately, there is very little information about the biological consequences of palsa disappearance (Luoto et al. 2004).

In addition to high-alpine fell-field vegetation and vegetation on cryosoils, snow-bed vegetation is regarded by IPCC as most sensitive to climate change in Fennoscandia, and their coverage is anticipated to decrease rapidly (see: http://www.grida.no/climate/ipcc_tar/wg2/500.htm). Given limited resources, it would be feasible to focus into monitoring a small set of clearly definiable habitat types which are characteristically northern and either vulnerable in a warming climate (snowbeds, palsa mires) and/or important from the perspective of feedbacks to climate change (palsa mires, treeline ecotones).

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5.3.2. Tree line ecotones

Tree lines are sensitive indicators of climate changes although the effects of climatic conditions often need time to be expressed via the regeneration, growth (often slow in harsh conditions), and mortality processes (Kulman 1998, Juntunen et al. 2002). Changes in tree line position result also in important feedbacks to climate systems because of changes in albedo and/or in the strength of carbon sinks (Harding et al. 2002). The tree line ecotones in NW-Europe (occurring around most of SCANNET field bases) are quite unique in a circumpolar context in the sense that there are both coniferous and deciduous (birch) tree lines, the latter often reaching higher altitudes and latitudes. There is evidence about recent increases in pine tree lines (Kullman & Kjällgren 2001, Juntunen et al. 2002; cf. also Virtanen et al. 1996) but the situation with mountain birch tree line is more complicated because of interactions with defoliation by geometrid moths (e.g., Tenow 1996, Virtanen et al. 1998, Neuvonen et al. 1999).

It is clear that monitoring changes in tree lines is also important from the biodiversity perspective because the advance in forests causes loss of alpine and tundra habitats. There are ongoing tree line monitoring projects in Sweden (e.g., Kullman 1998, 2001, Kullman & Kjällgren 2001) and in Finland (Juntunen et al. 2002). Tree colonization is also monitored in the ECN terrestrial site in Cairngorms: http://www.ecn.ac.uk/sites/cairngorms.htm. The previous forests in Iceland have been largely destroyed during the last 1000 years but now there are reforestation programmes (to some extent also with exotic trees).

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6. Biodiversity of Vertebrates in the SCANNET Region

6.1. Introduction

More than 500 vertebrate species [both terrestrial (279) and marine (>260)] live in the North-Atlantic – NW-Fennoscandian area. This is only a small fraction (1.3 %) of the global number of described vertebrate species, estimated to be around 43'000. Amphibians and reptiles have especially low species richness in the SCANNET region. However, there are some groups (e.g., waders, salmonids) which are relatively speciose and characteristic in northern areas, and the distribution of some species is exclusively northern. Thus, biodiversity monitoring and conservation are important issues also in the SCANNET region when we aim at halting the loss of biodiversity and it's all levels (habitats, species, intraspecific genetic variation).

Although the NW Europe is in general in a more "natural" state than more southern areas, several of the northern vertebrates have strongly reduced (even locally extinct) populations. These include e.g., Wolf, Arctic Fox (which is the mammal species occurring in the largest number (7) of the nine SCANNET sites), Snowy Owl, Lesser White-fronted Goose, and Shore Lark. The reasons for the decline of the two latter species are probably also along the migration routes and/or in the overwintering areas. This highlights the fact that actions in northern areas are not sufficient for efficient conservation of the local biodiversity. Alien vertebrate species (especially the American Mink) can be a threat to native vertebrate species in many of the SCANNET focal areas.

Table 5. The estimated species richness of different orders of both marine and terrestrial (including fresh water) Vertebrates in NW Europe – North Atlantic Region ("SCANNET region") is shown below. The last column shows the global number of described species.

Numbers of vertebrate species in the SCANNET region:

	Terrestrial or fresh water	**Marine - pelagic**	Total	% terr.-f.w.	**Global total # of described spp.**
Fishes	**20**	**(>)220**	***240***	8	19100
Amphibians	**6**	**0**	***6***	100	4200
Reptiles	**3**	**0**	***3***	100	6300
Birds	**193**	**18**	***211***	91	9200
Mammals	**57**	**29**	***86***	66	4600
Total	279	267	***546***		***43400***

Some of the vertebrate groups are so species poor in the SCANNET region (and lack species with northern distributions) that monitoring their biodiversity would not be very informative. This applies especially to amphibians and reptiles. Freshwater fishes have relatively low species richness in NW Europe, but salmonids are well represented and show high intraspecific genetic diversity (in fact, there are varying opinions about the systematic status (species or subspecies?) of some taxa; according to some authors there are even endemic fish species in the area). Genetic "contamination" of the unique native fish populations can be a problem because of escapes from fish farms and extensive introductions of alien species/populations.

In addition to the intraspecific and species level biodiversity in the SCANNET region, it should be noticed that the northern animal populations show also other forms of diversity, like:
- Diversity of population dynamic behaviours (e.g., in northern vole and lemming populations) has fascinated researchers for a long time, and a variety of hypotheses has been generated to explain them;
- Diversity of life history, behavioural, and physiological adaptations to cope with the harsh environmental conditions.

6.2. Annotated SCANNET check-lists of vertebrates in NW-Europe & NE Greenland

Baseline information on species diversity (various terrestrial and freshwater taxa) has been assessed at different spatial levels from sites to natural historic provinces. In Fennoscandia floristic and faunistic data is often shown as occurrence in 'natural historic provinces' (e.g., Collingwood 1979). Corresponding geographical division for Greenland ("floristic provinces) can be found in Böcher et al. (1966) and for Iceland in Löve (1983; cf. also Jonsell & Karlsson 2000). There are nine SCANNET 'field bases' or 'nodal areas'. Most of these represent larger geographical areas, and here we define these "larger geographical areas" as 'natural historic provinces' commonly used in Nordic Floristic and Faunistic literature. The correspondence between the 'SCANNET nodes" and these 'provinces' is shown in Table 6.

Table 6. The relationships between SCANNET field bases (or "SCANNET nodal sites/areas") and surrounding larger geographical areas.

SCANNET "nodal site - area"	"province"	country
Zackenberg	**northern continental East-Greenland (Grönland CEn)**	Denmark
Littla Skard	**Western Iceland** [1]	Iceland
{Sornfelli - Streymoy}	**Faroe Islands**	Denmark
Ny Ålesund	**Svalbard - Spitsbergen**	Norway
{Banchory-Cairngorms}	**Scotland**	U.K.
Dovre	**Opland (Opl)** [2]	Norway
{Abisko - Torneträsk area}	**Torne Lappmark (T.Lpm.)**	Sweden
{Kilpisjärvi - NW Enontekiö}	**Enontekiö Lapland (EnL)** [3]	Finland
{Kevo - Utsjoki}	**Inari Lapland (InL)**	Finland

[1]: In some cases data representing thw whole Iceland is shown.
[2]: Actually, Dovre area spans over several "provinces": Opland, Sør-Trøndelag, Hedmark, and to a small extent also Møre og Romsdal.
[3]: Note also that Kilpisjärvi is situated very close to "provinces" in Sweden (Torne Lappmark) and in Norway (Troms).

This hierarchical spatial "scaling" allows a more informative presentation of the geographical/regional occurrence of different species. Furthermore, the nature of occurrence of each vertebrate species in (or around) each SCANNET nodal area and/or corresponding province is shown as follows:

X = regular breeder; **Z** = regular visitor; **o** = occasional.

A symbol in parentheses means that it applies to the more southern (or lower altitude) part of the natural historic province in question. E.g., the following combinations may occur:

(X) = does not occur in the smaller focal area, but breeds regularly in the southern parts of the province
o(X) = occasional in the smaller focal area, but breeds regularly in the southern parts of the province
Z(X) = regular visitor in the smaller focal area, but breeds regularly in the southern parts of the province
(Z) = does not occur in the smaller focal area, but a regular visitor in the southern parts of the province
o(Z) = occasional in the smaller focal area, and regular visitor in the southern parts of the province
(o) = does not occur in the smaller focal area, and occasional in the southern parts of the province

For species having mainly Arctic/Alpine breeding habitats, the following combinations may occur:

X(Z) = breeds (in the upper parts of the landscape) in the smaller focal area, but only a regular visitor in the southern parts of the larger area (province)
X(o) = breeds (in the upper parts of the landscape) in the smaller focal area, but only occasional in the southern parts of the larger area (province)

References:
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6.3. Monitoring Biodiversity of Vertebrates in the SCANNET Region

There are great differences in the monitoring of biodiversity of different Vertebrate groups in northern Europe. Coordinated projects for biodiversity monitoring of freshwater fish or amphibians and reptiles in the SCANNET region do not exist. The situation is somewhat better with Mammals, and clearly best with Birds. Comprehensive biodiversity surveys and/or monitoring require extensive spatial coverage and time referenced and spatially explicit (geo-referenced) occurrence data with reasonable resolution (grid size).

Large-scale surveys or distribution mapping efforts (e.g., Bird Atlases) are generally national or international programmes where a large number of both amateur and professional ornithologists participate (e.g., every year over 2000 bird watchers participate in the BTO/JNCC/RSPB Breeding Bird Survey in Britain, and there were also over 2000 participants in the first national Bird Atlas of Finland; Hyytiä et al. 1983). Researchers and/or staff members of SCANNET field bases are often important contributors to these projects in northern areas (which generally are less well studied than more southern areas in Europe).

Distribution maps of European breeding birds at the quarter-UTM-grid scale (generally 50 km * 50 km 'squares') have been published by Hagemeijer & Blair (1997). The data in the Atlas of European Breeding Bird (EBCC/AEBB) is semi-quantitative (include estimates of numbers) for most of the SCANNET nodal areas included in this survey but qualitative (presence/absence information) for the Norwegian mainland. These results refer mainly to the time period in late-1980'ies although there were some variation in the exact data collection years between different countries (and, consequently, between different SCANNET nodal areas), as can be seen from Table 7. A further difficulty is that the time period from which the field records are collected/reported is not clearly reported in all publications, and even if the time period (normally 3-5 years) is reported, the exact years are not (this is generally no or only a minor problem, but in the case of rare and/or vulnerable species this kind of information might be valuable).

The regional/national Bird Atlas projects (see Table 7) generally have a resolution (grid size) of 10 km * 10 km (the Swedish Bird Atlas has 5 km * 5 km grid size) which is more informative than that used in EBCC/AEBB but still of sufficient size to include a good variety of the local habitats and also species with low population density.

Table 7. European and regional/national Breeding Bird Atlas projects(+ some surveys) in different SCANNET nodal areas. The numbers/symbols in the four last columns link to the references or Internet-addresses listed below the table.

Bird Atlases in the SCANNET nodal areas SCANNET field base	**Country/Region**	EBCC/AEBB* data collecting period	1970'ies	1980'ies	1990'ies	2000'ies
Zackenberg	NE Greenland				#	#
Litla-Skard	Iceland	1985-1995		4		
Sornfelli	Faroe Islands	1981-1989				
Ny-Ålesund	Svalbard	? 1950-1989(-1994) ?	1			**
Cairngorms/Banchory	U.K./Scotland	1985-1988(-1989)	2	5, 5b	5	****
Dovrefjell	Norway	? 1950-1989(-1994) ?		6		**
Abisko	Sweden	1986-1991		7	10	
Kilpisjärvi	Finland	1986-1990	3	8		***
Kevo	Finland	1986-1990	3	8		***
	Norway/Finnmark			9		

* = Hagemeijer, W.J.M. & Blair, M.J. (Eds) (1997) The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance. T & AD Poyser, London. 903 pp.
# = http://www.dmu.dk/1_Viden/2_Miljoe-tilstand/3_natur/biobasis/biobasis_rationale.asp#Birds
1 = Norderhaug, M. (1989) Svalbards Fugler. Dreyers Forlag A/S, Oslo. 102 pp.
2 = Sharrock, J.T.R. (Compiler) (1976) The Atlas of Breeding Birds in Britain and Ireland. T & AD Poyser. Calton. 276 pp.
3 = Hyytiä, K. Kellomäki, E. & Koistinen, J. (1983) Suomen Lintuatlas [Finnish Bird Atlas]. SLY:n Lintutieto Oy, Helsinki. 520 pp.; see also: Koskimies, P. (1989) Distribution and numbers of Finnish breeding birds. Appendix to Suomen Lintuatlas. Lintutieto. Helsinki. 76 pp.
4 = Skarphédinsson, K.H. (1994?) Atlas of breeding birds in southwestern Iceland. Icelandic Institute of Natural History. 126 pp.
5 = Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993) The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991. T & AD Poyser. London. 520 pp.
5b = Buckland, S.T., Bell, M.V., Picozzi, N. (Eds) (1990) The birds of North-east Scotland. North-east Scotland Bird Club, Aberdeen. 473 pp
6 = Gjershaug, J.O., Thingstad, P.G., Eldöy, S. & Bjyrkeland, S. (Eds) (1994) Norsk Fugleatlas [Norwegian Bird Atlas]. Norsk Ornitologisk Forening, Klaebu. 552 pp.
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10 = Svensson, S., Svensson, M. & Tjernberg, M. (1999) Svensk fågelatlas. Vår Fågelvärd, supplement 31, Stockholm. Sveriges Ornitologiska förening and ArtDatabank.
** = http://www.fugleatlas.no/
*** = http://www.fmnh.helsinki.fi/N_default.asp (Select Language: Finnish) -> Kartoitus ja seuranta -> Linnustonseuranta -> Kesäatlas [Finnish Summer Bird Atlas has been launched in 2000. It uses 1 km * 1 km squares and mapping (GIS) of bird territories. The study squares are concentrated in Southern Finland.]
**** = http://www.wildlifeweb.co.uk/atlas/ & http://www.bto.org/survey/bbsreport.htm

Other ongoing national or regional bird mapping, surveys, or observation projects can be found by following the links below:

- BirdLife International – Faroe Islands: http://www.birdlife.net/worldwide/national/faroe_islands_to_denmark/index.html
- Sveriges Ornitologiska Förening: http://www.sofnet.org/index.asp?lev=1&typ=1 -> Fågelrapportering)
  http://svalan.environ.se/rappsyst/index.htm
- BirdLife International – Sweden: http://www.birdlife.net/worldwide/national/sweden/index.html
- BirdLife International – Norway: http://www.birdlife.net/worldwide/national/norway/index.html
- Finnish Monitoring Project Birds of Prey: http://www.fmnh.helsinki.fi/N_default.asp
  ➔ (Select Language: English) -> Ringing Centre -> Research -> Birds of Prey
- BirdLife International – Finland: http://www.birdlife.net/worldwide/national/finland/index.html
- Royal Society for the Protection of Birds (RSPB) – bird conservation issues in Scotland: http://www.rspb.org.uk/scotland/index.asp
  http://www.rspb.org.uk/scotland/action/goldeneaglesurvey.asp (Golden Eagles in Scotland)
  http://www.rspb.org.uk/science/birdweb/results/index.asp (results of several bird survey projects)

- Scotland's Bird Club: http://www.the-soc.fsnet.co.uk/
  - ➔ Surveys
  - ➔ Bird recording in Scotland
- BirdLife International – U.K.: http://www.birdlife.net/worldwide/national/united_kingdom/index.html
- Icelandic Society for Protection of Birds: http://www.fuglavernd.is/enska/intro.html
- BirdLife International – Iceland: http://www.birdlife.net/worldwide/national/iceland/

Concluding, the most promising vertebrate group for biodiversity monitoring in the SCANNET region is undoubtedly birds. These are species rich, well known [both by professional researchers and by a large group of amateurs (with high level identification skills), including local residents in the area], many of the species have characteristically northern distributions, and reliable monitoring methods are available for different groups and habitats (e.g., Koskimies & Väisänen 1991). Mammals are relatively speciose in the area, but many of them are difficult to observe, and different subgroups (families) would require their own monitoring methods.

Reference:

- Koskimies, P. & Väisänen, R. A. (1991) Monitoring bird populations. A manual of methods applied in Finland. Zoological Museum, Finnish Museum of Natural History, Helsinki. 145 pp.

6.4. Fishes, Amphibians and Reptiles

Although there are over 200 marine fish species in northernmost Atlantic, only about tenth of that number freshwater fish species can be found in the SCANNET region. Some of the freshwater fishes spend part of their life in the sea. Salmonids are most typical freshwater fishes in this area. Many species have characteristically northern distributions, and they indicate high water quality. The number of fish species is especially low in the islands of North-Atlantic (e.g., Christoffersen 2002). In many northern areas freshwater fish species are an important source of food for the local residents. Furthermore, tourism based on fishing salmon, trout, or arctic char can be an important source of income in many areas. For example, salmon fishing along the Teno/Tana River is very important for the local economy in the surroundings of Kevo. Genetic contamination from salmons escaping from fish farms in Norway, as well as the potential spread of the parasite *Gyrodactylus salaris*, are considered as serious threats both for the local economy and biodiversity at the intra-specific level.

Amphibians and reptiles have generally southern distribution and thus there are not many species occurring in the SCANNET region. Less than 0.1 % of the combined global species number of these groups live in this area. Of the about 70 European amphibian species only six (9 %) and of the about 120 European non-marine reptiles only three (2.5 %) occur in the SCANNET region. The highest species richness is in Scotland (5 amphibians + 3 reptiles) while four of the SCANNET focal areas (Greenland, Iceland, Faroes, Svalbard) do not have any amphibians nor reptiles.

Distribution maps of European amphibians and reptiles have been published by Gasc et al. (1997) and they can also be seen here: http://www.gli.cas.cz/SEH/atlas/atlas.htm. None of the amphibian nor reptile species are unique to the area or have a generally northern distribution. In fact, with the expection of Common Frog (*Rana temporaria*) and Common Lizard (*Lacerta vivipara*) other amphibians or reptiles only marginally enter to the SCANNET region.

References:

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6.5. Birds

Birds are probably the best known group of organisms globally and this holds true also for northern Europe. There are more than 200 breeding bird species (2.3 % of the global bird species number; about 43 % of the European bird species pool) in the SCANNET region. Passerine birds are not particularly well represented, while waders have here their highest species in Europe and also waterfowl (swans, geese, and ducks) show high species richness. The European Arctic and Sub-Arctic is an important breeding area for many species over-wintering in more temperate regions in Europe or even in tropical Africa or Asia. Table 8 shows some bird species with characteristically northern distribution in Europe, the number of SCANNET nodal areas where they occur, qualitative estimates of their population trends (mainly based on Väisänen et al. 1998 and Hagemeijer & Blair 1997), and their classification with respect to European Conservation Concern and Threat Status.

Information about the conservation status of bird species occurring in the SCANNET region is mainly based on the classification by Tucker & Heath (1994) as applied by Hagemeijer & Blair (1997). Some examples are discussed in the light of personal observations and/or communications from SCANNET Station Managers. The classification of Species of European Conservation Concern (SPECs) is as follows (Hagemeijer & Blair 1997):
SPEC 1: Species of global conservation concern because they are classified as Globally Threatened, Conservation Dependent, or Data Deficient in "Birds to Watch 2: the World List of Threatened Birds" (Collar et al. 1994);
SPEC 2: Species whose global populations are concentrated in Europe (i.e., more than 50 % of their global population or range in Europe) and which have an Unfavourable Conservation Status in Europe;
SPEC 3: Species whose global populations are not concentrated in Europe, but which have an Unfavourable Conservation Status in Europe;
SPEC 4: Species whose global populations are concentrated in Europe (i.e. species with more than 50 % of their global population or range in Europe) but which have a Favourable Conservation Status in Europe.

The European Threat Status categories can be summarized as follows (Hagemeijer & Blair 1997):

European population size/trend	**<250 pairs**	**<2500 pairs**	**<10000 pairs**	**>10000 pairs**
No decline	Endangered (**E**)	Vulnerable (**V**)	Rare (**R**)	Secure (**S**)
Moderate decline	Endangered (**E**)	Endangered (**E**)	Vulnerable (**V**)	Declining (**D**)
Strong decline	Endangered (**E**)	Endangered (**E**)	Endangered (**E**)	Vulnerable (**V**)

Additional characterization is for Localized (**L**) species if more than 90 % of the population occurs in no more than 10 sites; for Winter (**W**) population criteria the thresholds above (# of breeding pairs) should be multiplied by four to get the respective thresholds as numbers of individuals of the flyway population levels.

As seen from Table 8, many characteristically northern bird species/populations show extensive fluctuations (often 3-5 years intervals), which makes the detection of population trends difficult. The reasons behind the fluctuations are generally drastic fluctuations in the food sources (lemmings/voles for hawks, owls, and skuas; seeds for granivorous passerines like Arctic Redpoll) or variable predation pressure due to lemming/vole-eaters switching to alternate prey during microtine lows (some geese, ducks, waders, and Tetraonids). Below some of the bird species and species groups are discussed to illustrate their status in the SCANNET region and the variety of threats they are subjected to.

Lesser White-fronted Goose (LWfG; *Anser erythropus*) has apparently been earlier (in the beginning of 1900-century; the Fennoscandian population was estimated to be over 10'000 individuals at that time) an abundant breeding species in the surroundings of three of the SCANNET field bases: Abisko, Kilpisjärvi, and Kevo. The strongest decline happened probably around 1950 (Soikkeli 1973). Nowadays LWfG is extinct or close to extinction in these areas, and also globally vulnerable (see the internet links below). The reasons for the decline are partly unknown, but probably habitat loss (transformation of steppes and marshlands to agricultural lands) and excessive hunting in the winter quarters (SE Europe and Asia) and during migration have played an important role. Hunting was also common in the breeding grounds over 50 years ago but the species has now been protected for many decades in Fennoscandia. Illegal (or legal in some countries) hunting during migration and wintering is still continuing. Some of the Scandinavian breeding grounds have been lost due to building of reservoirs for hydroelectric power. The importance of high reindeer grazing pressure in the breeding grounds or disturbance by tourists in some areas is unknown. Increased predation due to the spread of red fox towards north and higher altitudes has probably contributed to the decline of LWfG. At present, there are several ongoing projects aiming at the conservation of LWfG (see the internet links below).

The population development of another Arctic goose species, Pink-footed Goose (*Anser brachyrhynchos*), has been positive and so in striking contrast with that of LWfG. Pink-footed Goose also breeds in three SCANNET nodal areas (although totally different ones than LWfG): E-Greenland, Iceland, and Svalbard. Actually, the whole world population (about 230'000 in early 1990'ies) breeds in these areas. The wintering quarters are in British Isles (Greenland/Iceland population) and in Belgium, the Netherlands and Denmark (Svalbard population).

Several species of diving ducks are also characteristic for the ponds, lakes and rivers of European Arctic. Barrow's Goldeneye (*Bucephala islandica*) and Harlequin Duck (*Histrionicus histrionicus*) have mainly Nearctic distributions and are restricted to Iceland in Europe (the former furthermore confined to the Lake Mývatn and River Laxá area). Species like Scaup (*Aythya marila*), Long-tailed Duck (*Clangula hyemalis*), Common Scoter (*Melanitta nigra*), and Velvet Scoter (*Melanitta fusca*). The population trends of many of these species have been negative (see Table 8). A major breeding concentration of Scaup is at Lake Mývatn while the present densities in the Fennoscandian Arctic/Sub-Arctic are low. There have been clear regional differences in population trends of Scaup: in some areas populations have remained stable while elsewhere (e.g., Finnish Lapland) there have been drastic declines. The reasons for the declines in this group of species are not well understood, but many of these species over-winter in seas (e.g., Baltic Sea, North Sea) where they are susceptible to oil pollution, and some of the species suffer also from hunting during migration and/or winter.

Table 8. Selected bird species with mainly northern distribution, the number of SCANNET nodal areas where they occur, qualitative estimates of their population trends, and their classification with respect to European Conservation Concern and Threat Status (see text above). Population trends: **0** = no trend; **+** = increase; **-** = decline; **--** = severe decline; **F** = strongly fluctuating populations.

		SCANNET areas	Population Trends 1850/1900 ->	Population Trend 1970-1990	SPEC Category	Threat Status
Anser erythropus	Lesser White-fronted Goose	3	--	--	1	V
Anser brachyrhynchus	Pink-footed Goose	3		+	4	S
Aythya marila	Scaup	5		--	3*W	L*W
Clangula hyemalis	Long-tailed Duck	6		-	Non-SPEC	S
Melanitta nigra	Common Scoter	6		-	Non-SPEC	S
Melanitta fusca	Velvet Scoter	4	-	-	3*W	L*W
Buteo lagopus	Rough-legged Buzzard	5	-	F	Non-SPEC	S
Falco rusticolus	Gyrfalcon	6	--	0	3	V
Lagopus lagopus	Willow Grouse	5		-	Non-SPEC	S
Lagopus mutus	Rock Ptarmigan	8		F	Non-SPEC	S
Charadrius hiaticula	Ringed Plover	9		-	Non-SPEC	S
Eudromias morinellus	Dotterel	5	--	F	Non-SPEC	S (P)
Pluvialis apricaria	Golden Plover	7	- / +	-	4	S
Calidris temminckii	Temminck's Stint	4		--	Non-SPEC	S (P)
Calidris maritima	Purple Sandpiper	7		0	4	S (P)
Calidris alpina	Dunlin	9		0/-	3*W	V*W
Limosa lapponica	Bar-tailed Godwit	3		F	3*W	L*W
Stercorarius longicaudus	Long-tailed Skua	6		F	Non-SPEC	S (P)
Bubo scandiacus	Snowy Owl	3-5	--	F	3	V
Eremophila alpestris	Shore Lark	4		--	Non-SPEC	S (P)
Anthus cervinus	Red-throated Pipit	4		F(-?)	Non-SPEC	S (P)
Luscinia svecica	Bluethroat	4		+	Non-SPEC	S
Turdus torquatus	Ring Ouzel	5		0	4	S
Phylloscopus borealis	Arctic Warbler	3		0	Non-SPEC	S (P)
Carduelis flavirostris	Twite	5		0	Non-SPEC	S
Carduelis hornemanni	Arctic Redpoll	5		F	Non-SPEC	S (P)
Calcarius lapponicus	Lapland Bunting	4		F	Non-SPEC	S (P)
Plectrophenax nivalis	Snowbunting	9	-	-	Non-SPEC	S (P)

The worlds largest falcon, Gyrfalcon (*Falco rusticolus*) has a circumpolar distribution in the Tundra and Forest-Tundra biomes and it occurs in six of the SCANNET nodal areas: Zackenberg, Litla-Skard (Iceland), Dovre, Abisko, Kilpisjärvi, and Kevo. Gyrfalcon numbers have declined considerably during the last 100+ years. However, during the last decades there have been no major population trends. The main threats for Gyrfalcon are disturbance of nest sites, robbing of nests for falconry and egg-collections, and reduced numbers of prey (ptarmigan) (Koskimies et al. 1999). Snowy Owl [*Bubo scandiacus* (earlier *Nyctea scandiaca*)] is a nomadic species of the Circumpolar Arctic specialized on preying of the strongly fluctuating lemming and/or vole populations. It has suffered already in the early 20'ieth century from persecution and large-scale of collection of eggs (references in Väisänen et al. 1998). Furthermore, the irregularities in the population dynamics of microtines during the last decades may have caused problems for this species.

Waders are well represented in the SCANNET region (69 % of the European species pool). Even Svalbard has six regularly breeding (+ two occasionally breeding) wader species (European total = 45 breeding wader spp.). Some of the waders have shown population declines (Table 8). Historical reasons for declines have been e.g. overhunting for Dotterel and Great Snipe, and habitat changes and loss in over-wintering areas (Hagemeijer & Blair 1997). Large changes in the vegetation of Arctic regions have been predicted by combined climate change and ecosystems models: Tundra vegetation, the main breeding habitat of Arctic geese, ducks, and waders, will possibly experience major reduction (over 40 % by 2070). Major declines in the populations of several geese and wader species have been predicted (Zöckler & Lysenko 2000). As extensive Tundra loss under warming climate has been predicted especially for Siberian and Western Nearctic regions (Zöckler & Lysenko 2000), the north European – North Atlantic Arctic region may gain in importance as breeding grounds of Arctic Waterfowl and Waders.

There are only few European Passerine species with characteristically northern distribution. The Passerine Faunas of Arctic Islands are especially deuperate; e.g., Svalbard having only two (!; compare to the European number of Passerine species, which is >200) regularly breeding Passerine species: Wheatear (*Oenanthe* oenanthe) and Snow Bunting (*Plectrophenax nivalis*). Fennoscandian Shore Lark population has declined strongly during the last decades but the reasons are unknown. Passerine species like Twite (*Carduelis flavirostris*), Arctic Redpoll (*Carduelis hornemanni*), Lapland Bunting (*Calcarius lapponicus*), and Snow Bunting have their European breeding areas restricted to the SCANNET region. Scottish Crossbill (*Loxia scotica*) is the only endemic bird species for the region, but there are endemic subspecies both among passerines and non-passerines (see the SCANNET check-list).

References:

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- Zöckler, C. & Lysenko, I. (2000) Water birds on the edge: first circumpolar assessment of climate change impact on Arctic breeding water birds. World Conservation Press. Cambridge, UK.

See also:

http://www.birdlife.org.uk/action/science/species/sowb/p48-49.pdf (Climate change and Arctic birds) or http://www.panda.org/downloads/climate_change/birdsummary.rtf (WWF summary of Zöckler, C. & Lysenko, I. (2000) Water birds on the edge: first circumpolar assessment of climate change impact on Arctic breeding water birds)
http://europa.eu.int/comm/environment/nature/directive/birdactionplan/ansererythropys.htm (Action plan for protection of LWfG)
http://www.metsa.fi/natural/projects/lwfg/ (LWfG- Life-project)
http://www.piskulka.net/index.htm (Portal to the Lesser White-fronted Goose)
http://www.sofnet.org/index.asp?lev=263&typ=1 (LWfG pages of Sveriges Ornitologiska Förening)
http://folk.uio.no/csteel/nof/docs/projects/lesserwhitefronted.htm (Norwegian LWfG project)
http://www.wwf.fi/fennoscandian_lesser.html (Fennoscandian LWfG Conservation Project Annual Report 2000 / WWF)

http://herkules.oulu.fi/isbn9514259483/ (PhD-thesis: Minna Ruokonen (2001); Phylogeography and conservation genetics of LWfG)

6.6. Mammals

Mammals are rather well represented in the SCANNET region. The mammals in this area represent 1.9 % of the number of mammal species known from the whole world. Of the about 240 terrestrial mammal species of Europe 24% (57 spp.; excluding man; whales, dophins, seals, walrus, and polar bear classified as marine mammals) occur in the area. Of these 48 can be considered as native for the area while three species have been introduced from other parts of Europe and six species originate from outside of Europe. In addition, some other terrestrial mammal species have been occasionally found in the SCANNET region ("**o**" in the check-list).

The taxonomy of the annotated check-list of mammals in the SCANNET region follows mainly Wilson & Reeder (1993; see also: http://www.nmnh.si.edu/msw/), with the exeption of *Mus* species – *M. musculus* and *M. domesticus* are treated as separate species (Mitchell-Jones et al. 1999).

Furthermore: **nE!** = near extinction! **E** = extinct (from the area in concern)
o[X->E] = nowadays occasional, formerly breeding but now extinct (in the area in concern)
sd = semidomesticated (reindeer)
An additional "**I**" means that the species has been introduced (either intentionally or by "accident") from outside of the area (not necessary from abroad).

Distribution maps of European mammals have been published by Mitchell-Jones et al. (1999). Some mammalian families (e.g., rodents) are relatively well represented in the SCANNET region than others have mainly southern distributions. Many mammal species are difficult to observe, and different subgroups (families) would require their own monitoring methods. Larger mammal species can often be easily surveyed on the basis of snow tracks – the often long winter season in many SCANNET areas facilitates this. In the Arctic Islands the terrestrial mammal diversity is often so low, that all the species can be identified based on snow tracks. However, the SCANNET sites in Fennoscandia have several species of voles and shrews, which are not possible to identify to species level on the basis of tracks.

The population status of many large carnivores (wolf, brown bear, wolverine) is problematic in the SCANNET region [see: http://www.metsa.fi/suurpedot/seuranta/pohjoismaissa.html -> PowerPoint-esitys (a presentation prepared by Ilpo Kojola about the situation of large carnivorous mammals in the Nordic countries)]. Furthermore, the Arctic Fox is close to extinction in the mainland of Europe (see: http://www.zoologi.su.se/research/alopex/).

Scotland is the only SCANNET area where the invasive Gray Squirrel (from North America) is a problem threatening the native Red Squirrel population (see: http://www.snh.org.uk/ -> The Squirrel Strategy) although Red Squirrels occur also in many other SCANNET areas. On the contrary, the American Mink is a great threat to biodiversity (especially birds, buth other groups of organisms as well) in several SCANNET nodal areas.

References:
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See also:
http://www.metsa.fi/suurpedot/ [about large carnivors - in Finnish]

7. Biodiversity of Invertebrates in the SCANNET Region

7.1. Introduction

Invertebrates are an important link in most food webs and they are known to have a strong indirect influence on nutrient cycling and plant productivity (Malmqvist 2002; Mattson & Addy 1975; Neuvonen 1988). Thus, they form a valuable component of northern biodiversity. Furthermore, the distribution and dynamics of ectothermic invertebrates respond rapidly to climatic changes (e.g., Parmesan et al. 1999; Strahdee et al. 1993; Virtanen & Neuvonen 1999). The relevance of terrestrial invertebrates in monitoring the ecological effects of various anthropogenic environmental changes in Arctic areas has been shortly reviewed by Neuvonen et al. (1995).

More than 3500 invertebrate species are known to live in the subarctic – Arctic areas of NW Europe. Furthermore, this number is probably an underestimate because some speciose but taxonomically difficult groups (e.g., sawflies (Hymenoptera, Symphyta)) are poorly known. In general, the species richness of invertebrates decreases with increasing latitude, but some groups show relatively high species numbers in northern areas: e.g., spiders (Koponen 1993; Marusik & Koponen 2000), stoneflies (Lillehammer 1985), and sawflies (Kouki et al. 1994).

The knowledge about the biodiversity of various invertebrate groups in different SCANNET focal areas has accumulated during heterogeneous periods of time. Entomological studies in the Abisko area were very active already in the beginning of the last century (e.g., Brundin 1931, Malaise 1931; more references under the following subsections). However, interesting new findings of species even in relatively well known groups have been made also quite recently (e.g., Sahlén 1994) although in general the volume of entomological research appears to have declined. This is illustrated below with the distribution of hoverfly species records from Torne Lappland during different time periods (Fig. 4); Note: the numbers of recorded species reflect mainly variation in research activity (even during the most 'active' period, i.e. the first quarter of last century, only about a half of the total (cumulative) species number was recorded). Despite the long and intensive entomological research tradition in the surroundings of Abisko, some groups have remained poorly studied. E.g., in a recent catalogue of Chalcidoidea (a group of tiny parasitic wasps) with a total of 1725 Swedish species named, none were listed for the province Torne Lappmark and only 59 species were listed for Lule Lappmark (Hedqvist 2003).

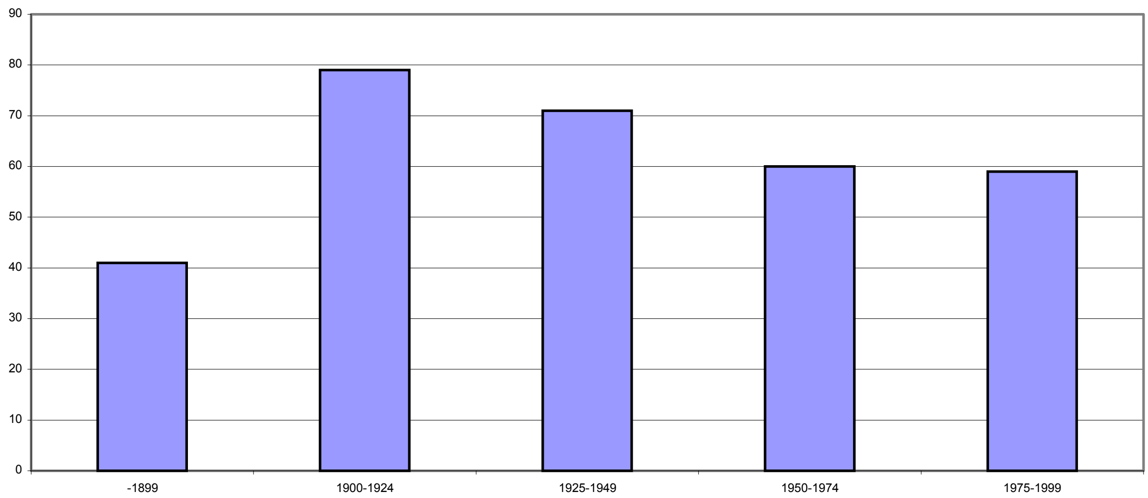

Fig. 4. The number of hoverfly (Diptera : Syrphidae) reported from Torne Lappmark during different time periods (based on: Bartsch 2001). The total number of species reported for the province is 144. Six species were not recorded after the year 1900.

References:

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7.2. Annotated SCANNET check-lists of selected invertebrate groups in NW-Europe & NE Greenland

Checklists of selected groups of both aquatic and terrestrial invertebrates in the SCANNET region have been prepared. The basis for selection has been data availability and quality (taxonomically difficult ("messy") groups not included) as well as feasibility/potential with respect to biodiversity monitoring. The checklists indicate the occurrence of species in each of the SCANNET nodal areas, but in addition, other species known from northern Europe (Nordic countries + U.K.) have been included. Some of these additional species may well be found in the SCANNET region in the future in a warmer climate (cf. Parmesan et al. 1999).

Four groups of aquatic insects have been included: Odonata (Dragonflies and Damselflies), Plecoptera (Stoneflies), Ephemeroptera (Mayflies), and Trichoptera (Caddisflies). Three first of these have rather modest species numbers while the fourth (caddisflies) is more species rich. As a background for the checklists, some general information about the groups, specific information about the research of these taxa in SCANNET areas, and their potential (and problems) for biodiversity monitoring are shortly discussed in subsections 7.3 and 7.4.1-7.4.3 below. With respect to terrestrial insects, checklists for the following groups are presented: Spiders (Araneae), Carabid beetles (Coleoptera, Carabidae), and Butterflies (Lepidoptera, Rhopalocera + Hesperidae).

Reference:
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7.3. Monitoring of the Biodiversity of Invertebrates in the SCANNET Region

Aquatic macroinvertebrates are commonly used as indicators of the health of freshwater ecosystems. The many reasons for their use biomonitoring as well as the ongoing monitoring programs in Nordic countries are discussed by Johnson et al. (2001), and are only shortly summarised here. In addition to their abundance and taxonomic richness, relatively easy collection and identification, more or less standardised sampling methodology, and generally good knowledge of their ecology, aquatic macro-invertebrates are important food for fish, and so their ecological importance is easily understood also by the general public.

There are several ongoing or planned monitoring programmes and/or research projects of aquatic invertebrates in NW Europe. The Scottish Environment Protection Agency and the Environmental Change Network monitor aquatic invertebrates at sites on most of the major watercourses in Scotland (http://dorset.ceh.ac.uk/River_Ecology/River_Communities/River_Communities.htm ; http://www.ecn.ac.uk/freshwater/river_north_summary.htm). The Countryside Survey 2000 records also the occurrence of aquatic invertebrates in a selection of 1-km squares across Britain (http://www.cs2000.org.uk/report.htm). Both the extent/intensity of macroinvertebrate monitoring and the taxonomic resolution used varies between different Nordic countries (Johnsson et al. 2001). Sweden appears to have the most extensive lake macroinvertebrate monitoring program while in Norway mostly streams are monitored. Abiskojaure and Latnjajaure are among the lakes monitored in Northern Sweden (Elfvendahl & Broman 2003).

The main monitoring sites in Iceland are River Laxá and Lake Myvatn in the northern parts of the country, although several other streams and lakes have also been sampled. Apparently, most of the above mentioned monitoring schemes are rather indepent of the SCANNET field bases – there is clearly a need for enhancing the information flow between the field bases and different stakeholders in this field.

The groups of aquatic invertebrates most promising for biodiversity monitoring are treated in more detail below (Subsections 7.4.1-7.4.3). Dragonflies and Damselflies (Odonata) are generally best known but only few of the species have characteristically northern distributions. The densities of Odonata larvae are generally sow low that the group is not well represented in studies of bottom faunas. The adults are easier to observe, but the dependence of flight activity on good weather may pose difficulties for the standardisation of monitoring protocols in northern areas with often rapidly varying and generally harsh weather conditions. Unfortunately, there seems to be no efficient traps for catching adult Odonata. Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) are easily caught both as larvae and as adults. The combined species number of these groups (EPT-index) is a commonly used measure in the context of water quality assesment. A more comprehensive biodiversity survey of these groups would benefit also from the use of different traps catching adults (emergence traps, light traps, Malaise traps, slit traps). The quick environmental quality assesment techniques using genus- or family-level identification are clearly not sufficient for biodiversity monitoring. It is also clear that a specialist focusing on a specific taxonomic group can find more species from an area than would be apparent from assesments made by non-specialists for other purposes than specifically surveing biodiversity.

There is extreme variation in the environmental conditions in the freshwater habitats in the SCANNET region, and consequently, the taxonomic groups discussed above (e.g., Odonata, Ephemeroptera, Plecoptera, Trichoptera) may not be suitable or sufficient for biodiversity moninoring in all areas. For example, in the physically harsher aquatic environments, like glacial rivers, chironomids in the subfalimilies Orthocladiinae and Diamesinae are dominating (Gislason et al. 2001). In Iceland there are 75 species of Chironomidae and in contrast only one species of Plecoptera, one of Ephemeroptera, and 11 of Trichoptera (Ólafsson 1991, Gislason et al. 2001).

Although coordinated biodiversity surveys of aquatic invertebrates at the SCANNET field bases are lacking, some of the individual studies give detailed geo-referenced information about the local distribution of species during previous decades, so that these data can be used as baseline information to detect temporal changes in future studies/monitoring. References to these studies are made below under the treatments of individual taxonomic groups.

Terrestrial invertebrates, like Spiders and Carabid beetles can be sampled easily with pitfall traps (Spence & Niemelä 1994, Neuvonen et al. 1995). Pitfall traps are regularly used in monitoring arthropods in Zackenberg (http://www.dmu.dk/1_Viden/2_Miljoe-tilstand/3_natur/biobasis/biobasis_rationale.asp#Arthropods). Pitfall traps were also used at Kevo during the IBP research in early 1970'ies (Koponen & Ojala 1975).

Butterflies are commonly surveyed when monitoring biodiversity in temperate areas, and there is an especially long tradition in Britain (Pollard 1977, Pollard & Yates 1993). Butterflies are relative species rich also in Alpine and Arctic habitats, which makes them potential candidates for monitoring also in the SCANNET region. Somerma & Väisänen (1993) reported on line-transect inventories in Annjalonji (NW-Enontekiö; NE from Kilpisjärvi) site in 1992; during one-week period in July a 3600 m long transect at this remote site was inventoried 11 times (two of which were discontinued due to inclement weather) and 27 Lepidopteran species (3087 individuals) were observed. Somerma (1995) proposed a line-transect on permanently marked routes (total length 500 m; marks at 5 m intervals in the field) for inventorying butterflies and day-flying moth in Saana near Kilpisjärvi. The protection of and research permissions for these two sites belong to two different authorities: Finnish Forest Research Institute is responsible for the Saana site while Metsähallitus (Finnish Forest and Park Service) is responsible for the Annjalonji site (Laasonen 1989). On average, 2-6 inventories are made annually on the Saana transects (Kuisma Ranta, personal communication). It may be so that inventories at Annjalonji have not been repeated (Liisa Kajala, personal communication). Inventories of the Lepidopteran fauna of Malla Strict Nature Reserve (near Kilpisjärvi) have been recently made for FFRI to find out the effects of reindeer grazing on biodiversity (Panu Välimäki, personal communication), and also with different trap types for general faunistic survey purposes (Pekka Sundell, personal communication).

Night-flying moths have been monitored with light-traps at several locations in Britain (Rothamsted Insect Survey) for already over three decades (Woiwod & Harrington 1994). Moths have also been monitored at Kevo since 1972 with four light-traps (Koponen et al. 1982). Light-traps have been used in Abisko only occasionally (Douwes 1975). The Finnish Moth Monitoring Scheme was launched in 1993 (Söderman et al. 1994), and it has 2 light-traps operating at Kilpisjärvi (FFRIs Research Station). However, there are some specific problems with light trapping as a monitoring method in northern areas (especially north of the Arctic Circle):

- the summer nights are light and consequently, the capture efficiency of light-traps is low during mid-summer;
- great annual variability in the timing of flight seasons -> light conditions and consequently, capture efficiency vary from year to year.

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7.4. Aquatic (Freshwater) Invertebrates

7.4.1. **Odonata** [Dragonflies and Damselflies; Trollsländor (S); Sudenkorennot (F)]

Dragonflies (Odonata: Anisoptera) and Damselflies (Odonata: Zygoptera) are remarkable aquatic insects, with generally southern distribution. They are large insects with beautiful colours, and relatively easy to identify. The group is well known (most of the European species described before 1850), and there are several excellent handbooks and field guides available (e.g., Hammond & Merritt 1997; Karjalainen 2002; Sandhall 1987; see also the Internet resources listed below).

Europe has only 128 Odonata species (>6000 spp. known in the world). The species richness of the group is relatively low in northern Europe, with 52 (Finland), 44 (Norway), 55 (Sweden), and 50 (UK) species recorded, and none breeding species in Iceland (the only species recorded from Iceland is *Hemianax ephippiger*, which is a rare vagrant from Africa!). Dragonflies have experienced serious declines in many parts of Central and Western Europe during the last century (mainly due to habitat loss and pollution; Tol & Verdonk 1988). However, the situation appears to be better in the north (Karjalainen 2002; but see also Olsvik & Dolmen 1992).

Dragonflies have conservation interest/value and they can be used as biodiversity indicators (Olsvik & Dolmen 1992; Sahlén & Ekestubbe 2001). Many Odonata species have often distinct habitat preferences, and the occurrence of different dragonfly/damselfly species can also be used as "habitat indicators" (Carle 1979).

In the SCANNET region Dragonflies and Damselflies are lacking from the most isolated areas (islands), i.e. Greenland, Iceland, Faroe Islands, and Svalbard. In other SCANNET nodal areas the species richness of Odonata varies from 13 to 18. The SCANNET Odonata check-list is based on the following sources: Hämäläinen (1984), Hammond & Merritt (1997), http://home9.swipnet.se/~w-90582/dragonfly/dragonfly.html (and personal information from Martin Peterson), Ólafsson (1991), Olsvik & Dolmen (1992), Karjalainen (2002). The check-list shows all Dragonflies (47 spp.) and Damselflies (24 spp.) known from northern Europe (Nordic countries + U.K.), with their status in each of the SCANNET nodal areas indicated.

Six species are common to the five SCANNET sites/areas in the continent or British Isles (from Scotland to Kevo, InL): *Coenagrion hastulatum, Enallagma cyathigerum, Aeshna caerulea, Somatochlora arctica, S. metallica, Leucorrhinia dubia*. The distribution of *Somatochlora sahlbergi* is restricted to the extreme North of European mainland. It has been found only from two SCANNET areas (Torne Lappmark and Inari Lapland; Sáhlen 1994; see also Valle 1931) but it probably occurs also in Enontekiö Lapland (= EnL; actually, the Swedish site is less than 30 km from EnL – see the map in Sáhlen 1994). It might become threatened under warming climate. Other species with predominantly northern distributions are *Aeshna caerulea*, *S. alpestris*, and *S. arctica*.

More detailed information about the distribution/occurrence of Odonata in different SCANNET nodal areas can be found from the following sources:
- Banchory/Cairngorms – Scotland: Hammond & Merritt (1997) present the Odonata records of whole British Isles (including Scotland) in 10 km * 10 km squares;
- Dovre – Opland: Olsvik & Dolmen (1992) presents records of endangered and vulnerable Odonata species in 10 km * 10 km squares in selected areas in Norway (including Dovrefjell area for one species);

- Kilpisjärvi – Enontekiö Lapland: Valtonen (1980) presents the Odonata records of whole Finland (including Enontekiö Lapland) in 10 km * 10 km squares;
- Kevo – Inari Lapland: Hämäläinen (1984) presents the Odonata records of Inari Lapland in 10 km * 10 km squares (records from a total of 52 squares).

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Some relevant Internet resources:
Nordisk Odonatologisk forum: http://hem.passagen.se/trollslaenda/nof/main_sv.html
Swedish Dragonflies: http://home9.swipnet.se/~w-90582/dragonfly/dragonfly.html
http://www.fly.to/dragonflies

7.4.2. **Plecoptera** [Stoneflies; Bäcksländor (S); Koskikorennot (F)]

The nymphs of stoneflies live generally in cool, clean streams with high dissolved oxygen content, although a few species can also occur in lakes (Lillehammer 1985). Streams are among the most threatened ecosystems on Earth (Dynesius & Nilsson 1994) but in the SCANNET region there still are many unregulated river systems. Stoneflies are obviously an excellent group for monitoring environmental degradation and invertebrate biodiversity of running waters. The species richness of the group is relatively low in northern Europe, with 36 (Finland), 35 (Norway), 37 (Sweden), and 37 (UK) species recorded; Iceland has one species. However, a total of 44 stonefly species occur in the SCANNET region (see the check-list below). Furthermore, in Fennoscandia the highest species numbers of stoneflies are found in areas north of the Arctic Circle (Lillehammer 1985).

The SCANNET Plecoptera checklist is based on the following sources: Meinander 1972, 1984, Lillehammer 1988, Nillson (1996), and Ólafsson (1991). It shows all Stoneflies (56 spp.) known from northern Europe (Nordic countries + U.K.), with their status in each of the

SCANNET nodal areas indicated. The species number in the five SCANNET sites/areas in the continent or British Isles (Scotland to Kevo, InL) varies from 21 to 28. Eleven species are common to all these areas. Despite small variation in species numbers among these areas, there seems to be considerable differences in species composition between different SCANNET nodal areas: Higlands of Scotland and Kevo/Inari Lapland have altogether 39 stonefly species but only one third (13 spp.) of these are common for both areas.

From the Abisko area – Swedish Lapland there are studies on stoneflies already from the first half of last century (Esben-Petersen 1920, Bengtson 1931, Despax 1938, Brinck 1949). Lillehammer (1985) has presented a zoogeographical comparison of stoneflies in different parts of Fennoscandia, dealing specifically with South-North, altitudinal (vegetation zone), and coast-inland gradients. In the mountains of Britain and Norway stoneflies have been studied with respect to conservation issues and as indicators of water quality (Bratton 1990, Brittain 1974, Fjellheim & Raddum 1992, Harriman & Morrison 1982). Stoneflies seem also to be well represented in the “Countryside Survey” of U.K. (see: http://www.cs2000.org.uk/). The frequency of occurrence of several stonefly species increased from CS1990 to CS2000 (Furse et al. 2002).

Stoneflies have been studied fairly systematically in the Kilpisjärvi area (Meinander 1972). They have not been extensively studied in the surroundings of Kevo but the knowledge is based on more or less incidental collecting by entomologists looking for other species (Meinander 1984). Meinander (1984) has predicted that an intensive study of stoneflies would almost certainly yield about 5 new species for the biological province of Inari Lapland, and the number recorded in the close proximity of Kevo (now 16) would also increase considerably.

Surveys on Plecopteran biodiversity might benefit if the slit-trap developed already in 1970’ies (Kuusela & Pulkkinen 1978) would become more commonly used. Three traps (close proximity to each other) run through one summer in NE Finland (67^{o}N) yielded some 17 species (2741 individuals); the species number is 74 % of that previously recorded from that biological province (Kuusela & Pulkkinen 1978).

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7.4.3. **Other groups** (Ephemeroptera, Trichoptera)

The species richness of **Ephemeroptera** [Mayflies; Dagsländor (S); Päivänkorennot (F)] is relatively low in northern Europe, with 54 (Finland), 45 (Norway), 59 (Sweden), and 54 (UK) species recorded; Iceland and Greenland have both one species. The SCANNET Ephemeroptera checklist is based on the following sources: Tiensuu 1939, Saaristo & Savolainen 1980, Savolainen & Saaristo 1984. It shows all Mayfly species known from northern Europe (Nordic countries + U.K.), with their status in some of the SCANNET nodal areas indicated.

Nøst (1985) studied the distribution of mayflies in four catchments in the Dovrefjell mountain area. He studied both subalpine and low alpine habitats and found 11(-13) species in 79 samples (>17500 individuals). Soldán (1981) studied mayflies in the surroundings of Kevo (Utsjoki); 41 localities representing all types of subarctic aquatic biotopes in the Teno river basin were studied during July 1981, and 24 species were found (3843 individuals), i.e. 80% of the species known from the area of Utsjoki municipality.

The species richness of **Trichoptera** [Caddisflies; Nattsländor (S); Vesiperhoset (F)] is relatively high in northern Europe, with 213 (Finland), 195 (Norway), 219 (Sweden), and 150 (UK) species recorded; even Iceland has 11 species, Faroe Islands 18, and Greenland 8. The SCANNET Trichoptera checklist is based on the following sources: Nybom 1984, Laasonen et al. 1998, Malicky 1978, Nilsson 1996, Ólafsson 1991. It shows 265 caddisfly species known from northern Europe (Nordic countries + U.K.), with their status in some of the SCANNET nodal areas indicated. At least 133 of these species occur in at least one of the SCANNET nodal areas.

Solem (1985) studied the distribution of caddisflies in the surroundings of Kongsvoll Biological Station in the Dovrefjell mountain area. He studied both subalpine and low alpine habitats (from 870 to 1630 m a.s.l.) with several methods (light, emergence, and Malaise traps, hand net collection of adults and picking of larvae), and found 60 species in the subalpine zone and 23 species in the alpine zone.

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Some relevant Internet resources:
http://entweb.clemson.edu/database/trichopt/hierarch.htm (Trichoptera-systematics)
http://www.funet.fi/pub/sci/bio/life/warp/hydroptila (Trichoptera-list of Finland)

7.5. Terrestrial Invertebrates

7.5.1. **Araneae** [Spiders] & **Carabidae** [Carabid beetles]

Spiders and Carabid beetles are predatory invertebrates living mainly in the bottom layer of vegetation. Both groups are species rich also in northern areas. They are easily caught by pitfall-traps, which makes it possible to design standardised sampling protocols. As ectothermic invertebrates they respond directly to the environmental changes at the site.

7.5.2. **Lepidoptera** [Butterflies & Moths]

Distribution maps of all European butterfly species have been published recently (Kurdna 2002). Of the SCANNET nodal areas, distribution maps with higher resolution have been published at least for Britain (Asher et al. 2001) and Finland (Huldén et al. 2000).

Many of the butterfly (or other Lepidoptora) observations in northern Finland/Sweden are made by amateurs/collectors who make occasional trips during their holidays. These observations are collected by national Entomological Societies, and they are published annually (e.g., Laasonen 1980, Holmberg 1999, Ohlsson & Ryrholm 1995). A major problem for using this information is the great annual variation in observation activity (Somerma &

Väisänen 1993). Amateurs have, however, an important role in the monitoring of endangered Lepidoptera as shown by the cooperation of the Lepidopterological Society of Finland and the Ministry of Environment (Kaila 1990).

Elmquist et al. (1994) listed Lepidopteran species found in the Duoibal(Tuoipal)-Pältsa area (northernmost Sweden, only 20 km from Kilpisjärvi Biological Station in Finland) during different inventories in 1954, 1956, 1964, 1978, and 1990 (only Macro-Lepidoptera recorded during the two first inventories). A total of 167 species of Lepidoptera were listed from the area, which is much smaller than the 337 species recorded from the nearby Kilpisjärvi-Saana-Malla-Annjalonji area in Finland – the large difference can be explained by the easier accessibility of the Finnish sites which are hence better studied (Elmquist et al. 1994). The species number of Butterflies (+ Skippers) observed in the Duoibal-Pältsa area during different years varied from 13 to 18 (with a cumulative total of 26 species, 10 of which were observed during every year). A common difficulty in inventorying Butterflies in northern areas is the often short flying periods, annual variation in the timing of the flight, and bad and rapidly changing weather conditions (Elmquist et al. 1994, Marttila 1995, Mikkola 1992, Somerma & Väisänen 1993).

The Lepidopteran fauna of the Kilpisjärvi area is well known (Krogerus 1972). Near Kilpisjärvi in NW-Enontekiö, two biologically rich sites [the southern slopes of Saana (165 ha) and Annjalonji (175 ha)] were protected in 1988 to save the sites from the negative effects of tourism and collecting (Väisänen and Somerma 1988). These are botanically and lepidopterologically very important sites with several rare or threatened species. In some small sites with especially rich Flora and Fauna habitat destruction due to increasing tourism and resulting erosion can be a problem (Väisänen & Somerma 1988). Information about the Lepidopteran fauna in the surroundings of Kevo has been summarised by Koponen et al. (1982), and that for the surroundings of Abisko by Brundin (1931) and by Nordström (1955). The latter reference is also useful for the Dovre area.

References:

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See also:
http://www.butterfly-conservation.org/index.html?/media/biodiversity/index.html
- ➔ BC UK
- ➔ Scotland (Butterfly Conservation in Scotland)

7.5.3. **Other groups** (pollinators, sucking herbivores, parasitoids)

It's clear that the terrestrial invertebrate groups discussed above (predators like spiders and Carabid beetles, chewing herbivores like Lepidoptera) may give only a limited view about the biodiversity, especially when considering the various ecosystem services to which different insect groups contribute. For example, bumblebees (Bergman et al. 1996) and hoverflies (Nielsen 1999, 1998) are important pollinators of northern plants, sucking herbivores like Homopteran can spread plant diseases, and Hymenopteran and Dipteran parasitoids can contribute to the protection of plants from excessive herbivory.

Compilation of background information from the SCANNET of the groups discussed above will remain as a task for the future. There are several difficulties, not least due to high species richness, difficulties in identification and taxonomy, and the small number of experts for many of these groups. Just one example about the scale of variation in the species richness of an important pollinator group in the SCANNET region is given here. Over 100 hoverfly species can be found in local faunas in the mainland of northern Europe (at 69^o N – about 100 km SE from Kevo; Nielsen 1998), but only three hoverfly species have been found in Spitsbergen (Nielsen 1999).

References:
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8. Biodiversity of Plants in the SCANNET Region

8.1. Introduction

An excellent resource for a general introduction to the vascular plants in most of the SCANNET region (unfortunately, Greenland is not covered here) is "Den Virtuella Floran" (in Swedish) by Arne och Anna-Lena Anderberg - a project of Naturhistoriska riksmuseet

(Sweden): http://linnaeus.nrm.se/flora/ . "Den Virtuella Floran" is written in Swedish but it has also index of scientific Genus-names: http://linnaeus.nrm.se/flora/index/slakte/welcome.html

It covers not only the scientific names of Nordic vascular plants but their common names in Swedish, Danish, Norwegian, Finnish, English and German as well as a lot of other information. The geographical distribution of most species is shown both in the Nordic countries (based on Hultén 1971) and in the northern Hemisphere (based on Hultén & Fries 1986). Protected species are presented both at country (based on information from Swedish Environmental Protection Agency 1999) and county level (based on information from Swedish County Administrations 1996). Furthermore, poisonous plants and species that are or can be used by humans are also presented. Nomenclature of the flora is often conservative which means that it does not follow the latest changes of the species names. For more current information about changes in plant names, "Checklista över Nordens kärlväxter" is recommended: http://www.nrm.se/fbo/chk/chk3.htm.

8.2. Annotated SCANNET check-list of Vascular Plants in NW-Europe & NE Greenland

The check-list is based on the following sources: Aronsson (1998), Böcher et al. (1968), Fosaa (2000), Löve (1983), Mäkinen & Kallio (1979). There might become changes in the nomenclature when the Panarctic Flora Project (http://www.toyen.uio.no/panarctflora/) has finished its work.

References:
- Aronsson; M. (1998): Torneträskområdets kärlväxter.
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- Mäkinen, Y. & Kallio, P. (1979): The vascular plants of Inari Lapland, Finland. Kevo Notes 4. Turku.

Some relevant Internet resources:
Denmark: Flora Danica: Natural history: http://www.billeder.dnlb.dk/
Iceland: Checklist of the vascular plants of Iceland: http://www.floraislands.is/plantlist.htm
Norway: Alphabetical list of vascular plants of Svalbard: http://www.ibg.uit.no/okbot/svalbplt.htm
http://www.ntnu.no/vmuseet/hager/kongseng/beyond.html (Kongsvoll Alpine Garden in the Dovre area)
http://www.uib.no/bot/qeprg/dovre.htm (another summary of the Dovre area)

8.3. Monitoring Biodiversity of Plants in the SCANNET Region

The biodiversity related research with plants spans over different spatial scales from plot size community studies [like ITEX (**I**nternational **T**undra **E**xperiment) and GLORIA (**Gl**obal **O**bservation **R**esearch **I**nitiative in **A**lpine Environments)] via landscape and regional scale floristic inventories/analyses (e.g., Heikkinen & Neuvonen 1997) to continental scale mapping projects (e.g., Atlas Florae Europaeae, see below). Most of the SCANNET field (or some other sites not very far) bases are contributing to ITEX, and some also to GLORIA, as can be seen from Table 9. Manuals for both ITEX and GLORIA are available. The ITEX research in Iceland is not at Litla-Skard but in Thingvellir and Audkuluheidi, that in mainland (alpine) Norway is in Finse, and that in Swedish Lapland is in Latnjajaure which is very close to Abisko. GLORIA is based on a Multi-Summit Approach, see:
http://www.gloria.ac.at/res/gloria_home/

➔ Multi Summit Approach. Links to the European GLORIA sites can be found more directly via: http://www.gloria.ac.at/res/gloria_europe/default.cfm.

Especially the SCANNET field bases, which have been functioning for longer time in remote areas (Ny Ålesund, Dovre/Kongsvoll, Abisko, Kilpisjärvi, and Kevo), have been important contributors/facilitators for collecting floristic data in their surroundings. Furthermore, many of the SCANNET field bases in Fennoscandia (specifically: Abisko, Dovre & Kilpisjärvi) occur in floristically very rich and interesting areas where the species richness of basophilic Arctic-Alpine plants is high, as can be seen from the map in: http://www.helsinki.fi/kilpis/kilpis_esite_eng_171203_72dpi.pdf. Although the Kevo is outside the Scandes mountain chain (which contains areas rich in limestone and/or shingles), it also has some unique or interesting floristic features like the occurrence of *Dryopteris fragrans* and *Epipogium aphyllum*. Although the plant species richness in the sub-Arctic or Arctic Islands (Greenland, Iceland, Svalbard) is quite low, their floras include some unique elements, which are rare or non-existing elsewhere in Europe.

National and/or regional floristic mapping projects have been running in many of the SCANNET nodal areas. The Atlas of the British Flora (Perring & Walters 1982) is a classical example, including records from the Banchory/Cairngorms (Scotland) area. The mapping unit/accuracy has been 10*10 km grid squares. These results are now publicly available (thanks to the Natural History Museum) by postal area codes in the Postcode Plants Database: http://www.nhm.ac.uk/science/projects/fff/. The database currently contains about 90 % of the native British Flora (missing species are listed here: http://www.nhm.ac.uk/science/projects/fff/MissingPlants.htm).

The general distribution of different vascular plant species in the Nordic countries have been well known since the classical work of Hultén (1950). Furthermore, Gjaerevoll (1990) shows the distributions of Alpine plants in Norway.

Floristic inventories in the area surrounding Kilpisjärvi were started in 1930'ies. The mapping is in1 km^2 grid squares, about 600 squares of the ca. 3'500 km^2 study area in NW-Enontekiö have now been inventoried, and an Atlas is soon to be published (Väre & Virtanen 2005). Meanwhile, the project description (by Henry Väre & Risto Virtanen) can be found here (available only in Finnish):
http://www.fmnh.helsinki.fi/N_default.asp

➔ valitse kieli (select language) -> Suomi/Finnish -> Tutkimus ja kokoelmat -> Kasvimuseo -> Putkilokasvit -> Alueelliset kasvistoselvitykset -> Enontekiön kasvisto

Table 9. The links between SCANNET nodal areas and ITEX & GLORIA sites.

SCANNET nodal area	ITEX sites	www-links	GLORIA sites Multi-summit approach
Zackenberg	Zackenberg [74° 30' N; 21° 00' W]	1	
Iceland * (Littla Skard)	Thingvellir [64° 17' N; 21° 05' W]	2 & 2b	
	Audkuluheidi [65° 14' N; 19° 43' W]	3 & 3b	
Sornfjelli	Sornfelli [62° 00' N; 07° 00' W]	4	
Ny Ålesund	Ny-Ålesund [79° 56' N; 11° 50' E]	5	
Cairngorms	-		Creag Mhigeachaidh (742 m), Camp Cairn (904 m), ? (978 m), Sgoran Dubh Mor (1111 m)
Norway (Dovre)	Finse [60° 37' N; 07° 32'E]	6	Vesle Armodshokollen (1161 m), Veslekolla (1418 m), Kolla (1651 m), Storkinn (1845 m)
Abisko	Latnjajaure [68° 21' N; 18° 30' E]	7 & 7b	Rakkasvare (492 m), Kårsavagge (1000 m), Latnjachorru (1300 m), Kårsatjåkka (1560 m)
Kilpisjärvi	Kilpisjärvi [69° 47' N; 20° 45' E]	8	
Kevo	-		

1 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=43&SelectedSiteName=Zackenberg
2 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=8&SelectedSiteName=Thingvellir
2b http://www.systbot.gu.se/research/itex/thingvellir.html
3 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=20&SelectedSiteName=Audkuluheidi
3b http://www.systbot.gu.se/research/itex/audkuluheidi.html
* http://www.rala.is/itex/default.htm
4 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=19&SelectedSiteName=Sornfelli
5 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=25&SelectedSiteName=Ny-Alesund
6 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=24&SelectedSiteName=Finse
6b http://www.systbot.gu.se/research/itex/finse.html
7 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=10&SelectedSiteName=Latnjajaure
7b http://www.systbot.gu.se/research/latnja/itex.html
8 http://www.itex-science.net/research/sitedetail.cfm?SelectedSite=41&SelectedSiteName=Kilpisjarvi

Botanists from the University of Turku have collected an extensive set of geo-referenced floristic data in northernmost Finland during the last 50 years: about 5'500 grid cells (each 1 km^2) in the study area Inari Lapland (about 22'700 km^2) have been visited, and the plants in different habitats searched to yield lists of all vascular plants in the squares. The data is now in digital form at the Kevo Subarctic Research Institute (University of Turku). During the early period of the fieldwork (before 1971) field recording practise was slightly different from the more recent one (adopted when the the current national grid-system came into general use in Finland), and maps of the study area were not of especially good quality/accuracy. Because of that and of changes in the names of some places, there have been some difficulties in geo-referencing the older observations into the present grid-system (Lasse Iso-Iivari, personal communication). Some of the data (specifically, that of Kevo Strict Nature Reserve) has already been analysed with respect to environmental controls of species richness and richness of rare vascular plants (Heikkinen & Birks 1996, Heikkinen & Neuvonen 1997). The whole floristic database of Inari Lapland together with other geo-referenced data (e.g., geology, topography, remote sensing data, etc) in a GIS environment is a promising tool to enhance our understanding about the interrelationships between environment and biodiversity. The demonstration tour made by researchers in University of Turku as a part of the GBIF (Global Biodiversity Information Facility) demonstration project 2003 (see: http://gbifdemo.utu.fi) shows the value and usefulness of combining this kind of biodiversity information with other types of spatial data: http://gbifdemo.utu.fi/map_data/kevo/kevo_intro.htm.

Atlas Florae Europaeae (AFE) is a long-term project for mapping the distribution of vascular plants in Europe, launched by European botanists already about 40 years ago. Up to now, twelve Atlas volumes (Jalas & Suominen 1972-1994; Jalas et al. 1996, 1999) with 3270 maps have been published, accounting for more than 20% of the vascular plants of European flora. More information of AFE can be found by following the links below:
http://www.fmnh.helsinki.fi/N_default.asp

➔ valitse kieli (select language) -> English -> Mapping and Monitoring -> Atlas Florae Euroaeae (AFE)

The AFE maps use squares of ca. 50 x 50 km, based on the Universal Transverse Mercator (UTM) projection and the Military Grid Reference System (MGRS). The squares corresponding to the SCANNET field bases (excluding Zackenberg which is outside the AFE area) can be found following the links below:
http://www.fmnh.helsinki.fi/N_default.asp

➔ valitse kieli (select language) -> English -> Mapping and Monitoring -> Atlas Florae Euroaeae (AFE)

➔ mapping territories used in Atlas Florae Europaeae (at the bottom of the above web-page)

Litla-Skard	Iceland (*Islandia*)	**Is**
Sornfelli	Færöer	**Fa**
Ny-Ålesund	Svalbard	**Sb**
Cairngorms	Britain	**Br**
Dovre	Norway	**No**
Abisko	Sweden (*Suecia*)	**Su**
Kilpisjärvi & Kevo	Finland (*Fennia*)	**Fe**

Informative comparisons can be made (although AFE is at present far from complete) among different parts of SCANNET region (or whole Europe) by following the links below:
http://www.fmnh.helsinki.fi/N_default.asp

- ➔ valitse kieli (select language) -> English -> Mapping and Monitoring -> Atlas Florae Euroaeae (AFE)
- ➔ Statistics of vols. 1-11 (in the right column)
- ➔ Summary Maps
    - -> Number of species
    - -> Number of possibly extinct or extinct species
    - -> Proportion of established aliens, species with unknown status, possibly extinct, extinct or uncertain vs. number of native and present species
      Proportion of 'non-native' plant species in AFE 1-11

For example: (1) the number of vascular plant species (per 50 km * 50 km square) in AFE 1-11 in different SCANNET nodal areas is as follows:

# of species (in AFE Volumes 1-11):

<100 spp.	Iceland, Faroe Islands, Svalbard
100-200 spp.	Dovre, Abisko, Kilpisjärvi, Kevo
100-200 or 200-300 spp.	Scotland (Cairngorms)

(2) The number of possibly extinct or extinct plant species (in AFE Volumes 1-11) in different SCANNET nodal areas is as follows:

0 spp.	Litla-Skard, Sornfelli, Ny-Ålesund, Kevo
0 or 1-5 spp.	Dovre, Abisko, Kilpisjärvi
1-5 to 10-15 (25-30) spp.	Scotland (Cairngorms)

(3) Proportion of 'non-native' (meaning here: "established aliens, species with unknown status, possibly extinct, extinct or uncertain") vascular plant species (per UTM square) in AFE 1-11 in different SCANNET nodal areas is as follows:

0–5 %	Iceland (mostly), Faroe Islands, Svalbard, Dovre, Abisko, Kilpisjärvi, Kevo
5–10 to 15-35 %	Scotland

References:

- Gjaerevoll, O. (1990) Alpine plants. In: Berg, Y., Faegri, K. & Gjaerevoll, O. (eds.): Maps of distribution of Norwegian vascular plants. Trondheim, 123 pp. + 37 pl.
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9. Conclusions

Our knowledge of biodiversity at and around the different SCANNET field bases is very variable; observations vary widely between sites in both time (less than 10 to over 100 years) and space, as well as in taxonomic coverage and the intensity of studies. However, it has been interesting and rewarding to start compiling the existing information for selected taxa from different sources to make it better available for users. It's also evident that within the SCANNET region there is large variation (due to differences in isolation harshness) in biodiversity and in the factors driving its dynamics. Also the threats to biodiversity vary at different sites.

The standardisation and coordination of protocols at the **habitat/ecosystem level of biodiversity** around different SCANNET field sites would greatly benefit from the use of a common GIS framework. Collating the more detailed environmental and biological (vegetation types) information, and its combination with e.g. digital elevation models and geological data for all SCANNET nodal areas would be especially valuable. This will greatly help in understanding the responses of northern ecosystems to climate change (Press et al. 1998).

With respect to **species level biodiversity** research and monitoring SCANNET provides an interface to work assessing and developing protocols for the most efficient collection and dissemination of observational biodiversity data at the European level (http://enbi.utu.fi/). SCANNET field sites can provide an infrastructure where these protocols could be tested. The common and easy use of GPS makes now the recording of georeferenced observations much easier than during the early phases of surveying at SCANNET field bases. Furthermore, the use of spatially hierarchical sampling schemes (with grid-squares of the size of 1 ha, 1 km^2, 100 km^2, 2'500 km^2, 10'000 km^2) should be encouraged.

The previous and existing experiments and other research addressing **intra-specific variation** and adaptability at the SCANNET sites provide an extremely valuable resource to the European research community. Their efficient use by the researchers has been made better available by the metadata of these studies available at the SCANNET portal (http://www.scannet.nu). Furthermore, the excellent facilities and support for biodiversity surveys at many SCANNET field bases will be extremely valuable when the effects of environmental changes on the genetic variability and adaptation of northern organisms are studied (Molau & Alatalo 1998).

References:
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