Pechora River basin Integrated System Management PRISM

Pechora River basin Integrated System Management PRISM

Biodiversity assessment for the Pechora River Basin
Cluster B: Biodiversity, Land use & Forestry modeling

Theo van der Sluis

Institute Biology Syktyvkar **Alterra** **RWS-RIZA**

PRISM is a project under the Programme Water for Food and Ecosystems of the Netherlands Partners for Water

with support of NWO Netherlands Organisation for Scientific Research

Alterra-report 1156

Alterra, Wageningen, 2005

ABSTRACT

Sluijs, Th. Van der, 2005. *Pechora River basin Integrated System Management PRISM, Biodiversity assessment, Cluster B: Biodiversity, Land use & Forestry modeling.* Wageningen, Alterra, Alterra-report 1156. 94 blz.; 28 figs.; 23 tables.; 77 refs.

This report describes the biodiversity for the Pechora River basin Integrated System Management (PRISM). The Pechora River Basin, situated just west of the Ural Mountains, Russia, consists of vast boreal forests and tundra landscapes, partly pristine and undisturbed.
The concept of biodiversity is discussed and parameters are selected which are descriptive for biodiversity at both the landscape and stand level. Based on these parameters the biodiversity is assessed to describe or quantify impacts of certain forest or land use exploitation scenarios. The chosen parameters for biodiversity should therefore be meaningful for the expected or possible changes.
The biodiversity is described, based on field data which was collected for vascular plants, lichens, mosses, invertebrates, birds, mammals, fishes, reptiles and amphibians and benthos.
For the different taxa it is described and discussed what the biodiversity is of the Pechora River Basin, for the different land units that have been defined. The results are extrapolated to the River Basin level.

Keywords: biodiversity, boreal forest, forestry, land use, Pechora River, Red List, species diversity

ISSN 1566-7197

This report can be ordered by paying € 30,- to bank account number 36 70 54 612 by name of Alterra Wageningen, IBAN number NL 83 RABO 036 70 54 612, Swift number RABO2u nl. Please refer to Alterra-report 1156. This amount is including tax (where applicable) and handling costs.

P.O. Box 47; 6700 AA Wageningen; The Netherlands
Phone: + 31 317 474700; fax: +31 317 419000; e-mail: info.alterra@wur.nl

[Alterra-rapport 1156/02/2005]

Contents

Appendices

Acknowledgements

This report is based on field work that was done during two seasons for the Upper Pechora region, 5th of July-31st July 2002 and 24th of June-17th July 2003, as well as for the Pechora Delta.

The field data was collected by colleagues from the Institute of Biology, Syktyvkar (Komi Republic, Russia): S. Degteva, V. Ponomarev, T. Pystina, A. Kolesnikova, S. Kochanov, O. Loskutova, V. Elsakov, T. Shubina, and V. Shubina.

Furthermore, from the Ministry of Transport, Public Works & Water Management RIZA-Lelystad (The Netherlands) data was contributed by S. van Rijn, M. Roos and M. van Eerden.

Forest data was provided by Pieter Slim, ALTERRA, Wageningen (The Netherlands). R. Klaver Wageningen University (The Netherlands) processed and checked data for the database, and contributed to chapter 4 of this report.

H. Leummens and G. Vyturin assisted in field work and coordination.

I want to thank Project leader M. van Eerden, P. Slim and B. Pedroli for the critical reading of the concept of this report. Furthermore I would like to thank Mr. S. de Bie, (Environmental Advisor, Shell International BV) for his information.

The research reported here was funded by the Netherlands Partners for Water (project PRISM), and by the Netherlands Organisation for Scientific Research (NWO project 047.014.013, PRIST).

Summary

The Pechora River basin Integrated System Management (PRISM) project focuses on sustainable management of natural resources. The results of the project should give indications for more sustainable land use, in particular forestry management, oil and natural gas exploration and exploitation, mining and exploitation of aquatic resources such as fish. The project should also help in understanding natural processes in forests in Western Europe.

When aiming at a sustainable use of natural resources in a region, it is necessary to develop a measure of sustainability. This can be done, amongst others, by defining the biodiversity of areas, and to compare biodiversity for different management systems.

In this report the concept of biodiversity is explained. For PRISM biodiversity is assessed to describe or quantify impacts of e.g. certain forest exploitation scenarios. The chosen parameters for biodiversity should be meaningful for the expected or possible changes. So indicators should be sensitive to impacts of forestry, hydrological changes, land use changes as well as pollution and fragmentation.

To be able to define a meaningful measure of biodiversity, it is assessed which commonly used parameters for biodiversity are suitable for implementation in the framework of the PRISM project, for the Pechora River Basin. This is dependent on the available data, the sensitivity of the parameters, and the measures or scenario's which are foreseen in the project.

For the PRISM project biodiversity parameters have been selected based on their relevance for boreal forests (pristine and managed), the interventions which are foreseen in land use (which may include oil and gas exploitation) and forest exploitation, and the field data that has been collected.

At landscape/ecosystem the following are considered level relevant parameters: ecosystem rarity (e.g. number of rare or endemic species), landscape pattern (minimum critical ecosystem size), naturalness, representativeness of ecosystem type, and ecosystem processes.

At stand level, or local level: indicator species, species diversity, species rarity (e.g. number of Red List, rare, protected or endemic species), dead wood and structural diversity.

These parameters have been tested with the available field data for the different taxa. The biodiversity is described at regional level (i.e. based on the field work study areas) and landscape level (River Basin).

At the regional level the forest areas are very important for biodiversity: the highest species numbers and Red List species are found in spruce and pine forests. This is the case for birds, mammals, insects, vascular plants and lichens.

Anthropogenic areas have a high species richness for birds, and in particular along infrastructure (drainage ditches etc) for amphibians.
Also grasslands – in particular natural, riverine grassland, are important for vascular plants, lichens and insects. Similarly for aspen and birch forest, which are species rich for the same taxa.

Water and shore habitats are by definition very species rich in aquatic groups, fish and benthos, but also in vascular plants. Bird observations for the Pechora Delta has been classified according to MODIS classes, and are therefore not directly linked to the land units, but definitely highest species numbers would be found for the coastal habitats. Fens and bogs are in particular important for herpetofauna and moss species. The communities are however not species rich.

At the River Basin level the forest areas are very important for biodiversity: high species numbers and high numbers of Red List species for birds, mammals, insects, vascular plants, mosses and lichens are found in spruce and pine forests, mixed spruce, pine and birch forest as well as meadows.
The Northern tundra and boggy tundra has high bird species richness, and counts also many Red List species for birds. For other species groups data is lacking in the dataset used here.
Rich fen and poor fen are important for moss species mainly, but they are rather species poor, compared to other ecosystems.

Open water, which includes rivers and lakes, are rich in benthos and fish species – which is obvious since Modis includes all possible habitats in this one land cover type. The number of Red List species is in particular high for birds and mammals Sandbanks (coastal, as well as riverbanks) are important habitat for bird species and vascular plants.
Finally, coastal meadows have absolutely the highest bird species richness, and a high number of Red List species.

Looking at the overall study area and Red List species, we see concentrations of in the Southeastern part, i.e. the Zapovednik area, as a biodiversity hotspot, as well as riverine territories, along the Pechora River. This is mainly defined by the large list of Red List lichen species, and by the fact that for tundra areas only bird data was available.

In general the forest areas are very important for biodiversity: high species numbers and high numbers of Red List species for birds, mammals, insects, vascular plants, mosses and lichens are found in spruce and pine forests, mixed spruce, pine and birch forest as well as meadows.

Preface

The ever-increasing population of mankind imposes serious threats to the functioning of ecosystems all over the world. Many examples include degradation, pollution, disturbance and the extinction of plant and animal species. By contrast to many systems in the temperate and tropical part of the earth, the boreal and arctic regions are still largely unspoiled and less densely populated. In Russia the Pechora river is one of the few remaining river systems with an almost unchanged hydrological catchment. The surrounding landscape still consists of forests and, to a large extent, even pristine forests occur. Due to very large reserves of oil, gas, minerals and forestry products the economic exploitation of this region has, not surprisingly, started to develop.

The PRISM programme aims to contribute to a wise-use development of natural resources and investments are supposed to contribute to the sustainable development rather than over-exploitation of the environment.

Based on two years of joint co-operation, we are pleased to present the first outcome of a series of studies undertaken in this area. This report about biodiversity aspects of the river basin explores the different methods of how to assess the wealth of biological diversification. I'm glad that we took the opportunity to carry out field research with a multi-disciplinary team. Not only this provided new ways towards the answers to our questions, but also was very useful to build on old relationships and create new contacts. Good to mention the fact that this report focuses upon the upstream part of the basin. Having worked for quite a while in the Pechora delta, the upstream parts now deserve more attention. Therefore the author has concentrated on the questions, which relate to this area.

I wish the reader a lot of reading pleasure; I'm convinced that the necessity to extend the research into some new areas will be granted during the next few years.

Dr Mennobart van Eerden
General project manager PRISM
Pechora River Integrated System Management

1 Introduction

1.1 Pechora River Integrated System Management PRISM

The Pechora River basin Integrated System Management (PRISM) project focuses on sustainable management of natural resources. The results of the project should give indications for more sustainable land use, in particular forestry management, oil and natural gas exploration and exploitation, mining and exploitation of aquatic resources such as fish. The project should also help in understanding natural processes in forests in Western Europe.

A method for biodiversity assessment and natural resources management in the Pechora River Basin is necessary if a sustainable land-use is to be accomplished. Such a method is at present being developed in the framework of the PRISM project. First spatial data is collected and compiled on the abiotic (soils, hydrology) and the biotic systems (flora, fauna). This information is stored in a digitized form and made available to planners and decision-makers. Second, models are required to develop and evaluate different development scenarios. Important input data for such models are forest structure, forestry production and biodiversity. Models currently (further) developed in the PRISM project are the Pechora Basin Hydrological Model, the ForGra forestry model (Jorritsma *et al.,* 1999) and a biodiversity model. Based on these models the evaluation of different strategies for forest management should be possible as well as making predictions on forest production, regeneration and changes in biodiversity.

In Chapter one the PRISM project and the background of this study is introduced. General principles and concepts about biodiversity are presented in Chapter 2. The most commonly used parameters are presented in chapter 3, and biodiversity is assessed at regional level (field work areas; chapter 4) and Pechora River Basin level (Chapter. 5). Finally a discussion and conclusions on the best approach for biodiversity assessment in the boreal forests of the Pechora River Basin are presented in Chapter 6.

1.2 Description of the Pechora River Basin

The Pechora River Basin is situated in Russia at the eastern border of Europe, just west of the Ural Mountains (Figure 1). The Pechora River Basin is situated in the Komi Republic and Nenets Autonomous District. The total population in 2001 is some 632,700 people of which 65% are of Russian origin, 10% Komi (Buryan, 2002). Average population density is low with 1.4 person/km2 (Russian average 8.5 / km2). Population centres are small towns like Pechora, Ukhta, Vorkuta and Inta, and there are small dispersed settlements and villages. Most of the area however is not inhabited though. The Pechora Basin is larger than Germany and is covered with tundra in the north, and taiga (far northern, northern and middle taiga subzones) in the south forming part of the West-Siberian and North European taiga. Part of these forests has once been harvested, but still large areas can be regarded as pristine forests. They can be considered among the most important boreal forests that still exist in Europe (http://www.wcmc.org.uk/protected_areas/data/wh/komi.html).

Figure 1: Pechora River Basin, Russia.

The Pechora River is, with a length of 1809 km, one and half time as long and with a catchment basin of 288,000 km^2, twice as large as the river Rhine. The river itself is however almost in its natural state, with only one bridge crossing the river and no major river improvement works established (Ponomarev *et al.*, 2004). Only one railway line connects the northern industrial town of Vorkuta with the southern part of the Komi Republic, and the Russian hinterland, no roads are present in the north outside the few urban areas.

The local population makes a living in forestry, mining, agriculture, fisheries, and the oil industry. Due to recent economic changes many people are unemployed, and resort to illegal fishing and poaching, as only option to acquire some food. Some minor environmental problems are related to exploration of oil, natural gas, mineral resources, timber, and poaching. Forestry and mineral exploitation (oil, gas, minerals) are important economical activities in Komi. Several processing industries related to these are present, in particular Neusiedler-Syktyvkar, situated in Vychegda River Basin and one of the largest pulp and paper factory of Europe. Small scale farming activities, hunting, fishing and haymaking take place, concentrated around existing settlements and villages. Production is mainly for subsistence, since the infrastructure is very limited.

The Climate is continental, with extremely low temperatures in winter of 45 - 50^o C. below zero, in summer on average 17 degrees, with a maximum up to 30 degrees. Rainfall depends very much on the location, varying from 500-550 mm in the tundra zone, 650-750 mm in the taiga zone, to over 1200 mm in the highest parts of the Ural Mountains (Bratsev, 2002).

There are several large protected areas within the Pechora River Basin: in total 6 million hectares or about 14% or of the Komi territory is protected area. The largest reserves are situated in the Pechora basin: the Yugyd Va National park 1.9 million ha, established in 1993, and recently approved as a UNESCO Man & Biosphere Reserve, and the Pechora-Ilyich Zapovednik, which was established in 1930 and measures, with buffer zone, over 1 million ha (Degteva, 2002). In addition, the riparian zone of all rivers is protected up to 1 km from the main river or 500 m for smaller tributaries. This means that in principle no human activities such as building, industry and forestry are allowed in this zone. In practice however, this is not entirely implemented, although no large-scale forestry is found.

Over the past 80 years vast areas of mainly pristine forest have been harvested, with a steady increase from the forties onwards up to the eighties of the past century, when 26 million m3 were harvested annually (Figure 2). Low prices for timber have lead to a decrease in wood demand from this region, production being only some 5.5 million m3 per annum at present (Kozubow & Taskaev, 2000, Angelstam *et al.,* 1995).

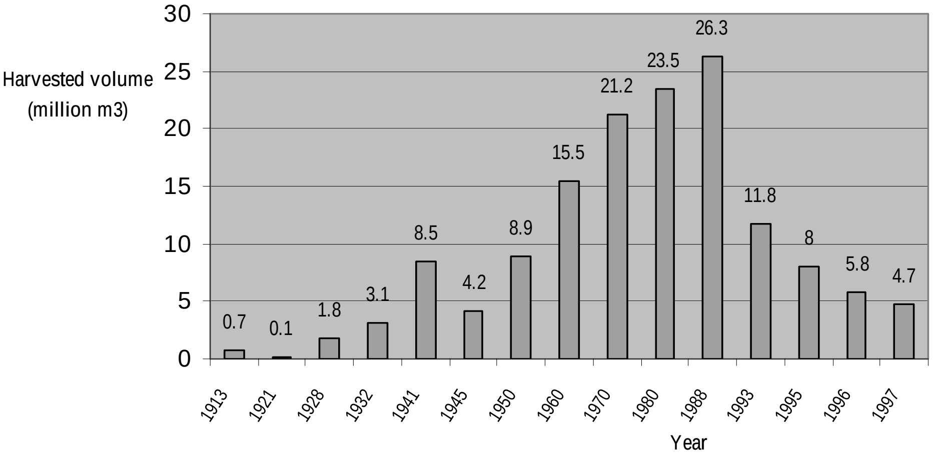

Figure 2: Harvested timber volume in the Komi Republic (Kozubow & Taskaev, 2000).

However, with more strict conservation policies being implemented in Western Europe, it is to be expected that demand will increase, leading to more harvesting, and eventually also increased pressure on pristine forests or valuable secondary forests. In addition, the following problems are encountered in forestry:

- large scale clear-cuts in primary forest;
- unsatisfactory regeneration after clear-cut, leading to commercially uninteresting stands as secondary forests;
- loss of biodiversity;
- small share of commercial stems and large losses of commercial stems at harvest;
- limited rural development because no value is added to the exported timber.

1.3 Why assessing biodiversity

Biodiversity is important as a unifying concept, in planning and conservation. Based on biodiversity areas may be identified which are of particular importance for conservation, and thus may require specific protection measures or a protection status.
Biodiversity, how complex it may be and how many different connotations it has, gives us also a better understanding of landscape processes, and scale levels at which diversity can be assessed.

When aiming at a sustainable use of natural resources in a region, it is necessary to develop a measure of sustainability. This can be done, amongst others, by defining the biodiversity of areas, and to compare biodiversity for different management systems.

Biodiversity is important in this research because it gives an indication on the state of the nature in the sampled areas. All the numbers on species abundance and diversity indices indirectly give a value to the state of nature in a certain ecosystem type.

It has been shown that high levels of (taxonomic) diversity guarantee ecosystem stability: ecosystems are less vulnerable towards (environmental) changes, and more easily stabilise after degradation (Kiessling, 2005).

1.4 Approach of this study

In the framework of PRISM, in 2002 and 2003 expeditions were held in the Pechora Basin, both in nearly pristine areas and areas where land use (mainly forestry, mining activities, fisheries, infrastructure) had a large impact on the ecosystem (Leummens *et al., 20*02, 2003) The work is based on a landscape approach: on the basis of ecosystem geomorphology, and vegetation Land Units are defined. All data that was collected is linked to this basis, the Land Unit (Appendix 1).
The flora and fauna were assessed: composition of lichens, mosses, vascular plants and mammals, birds, fishes, insects and herpetofauna (reptiles and amphibians). Plots of 400 m2 were sampled in different Land Units, for abiotic conditions, flora and insect composition. Transects of several kilometres were sampled in different Land Units to define composition of birds and mammals. Also different abiotic parameters were described in a multi-disciplinary approach: soil type, hydrology, geomorphology, and humus profile.

The data were collected in both natural and disturbed areas, so as to illustrate the impact of man on the ecosystem. These impacts are defined within this project, but also quantified with a measure of biodiversity. The results will be used in a DSS (Decision Support System) to illustrate man's impact on ecosystems, but also to extrapolate the effect of certain development scenarios.

In order to analyse species abundance per Land Unit, specific data of one group (insects, birds, benthos etc.) collected in one Land Unit is compared to the same groups' data in a different Land Unit. Comparisons of species abundance of different Land Units can only be made when the sampling techniques are similar in a statistically correct manner.

Biodiversity assessments were done at two levels: at relevé level (based on field data; chapter 4) and on River Basin level (extrapolation of field data and basin-wide maps; chapter 5).

The areas identified for field expeditions are presented in Figure 4 and include both the upstream and downstream (Delta) sites.

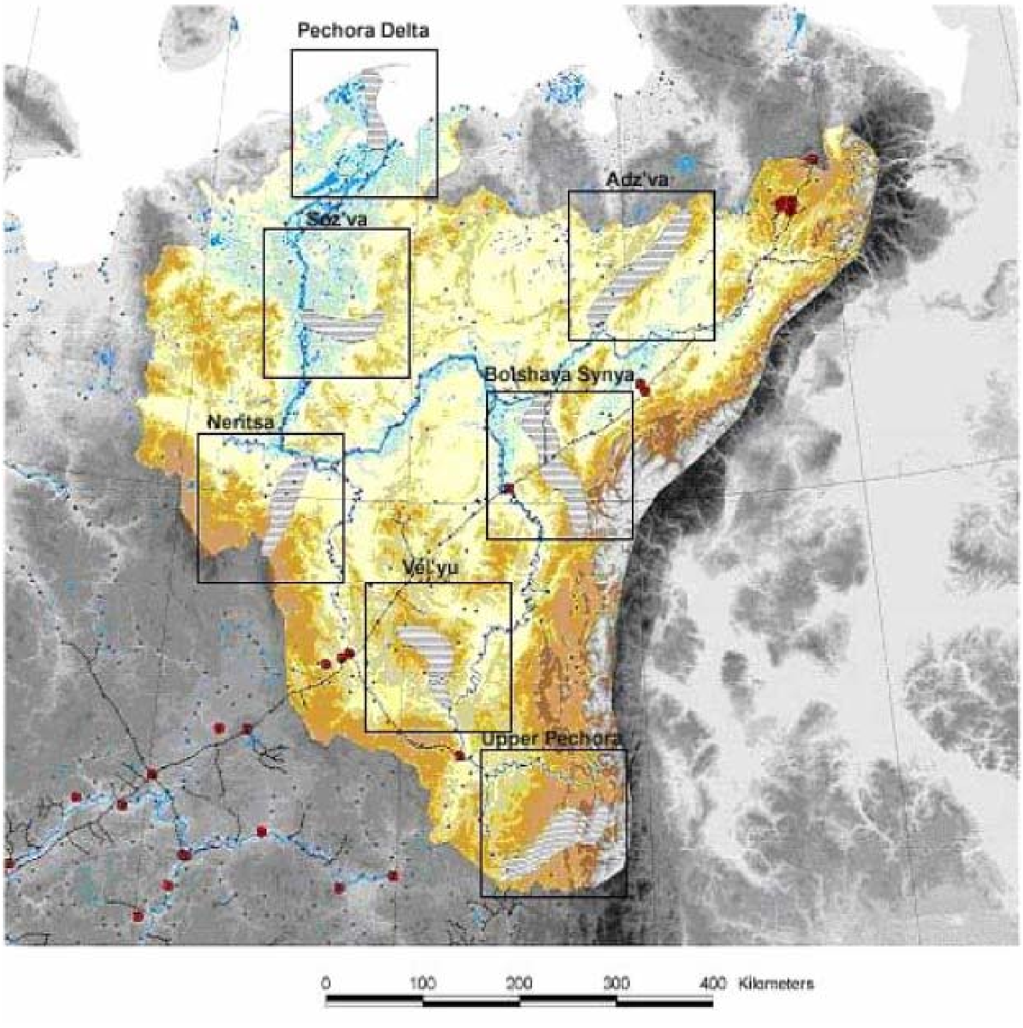

Figure 3: location of field work areas; the Pechora Delta, Bolshaya Sinya, Vel'yu and Upper Pechora.

In 2002 field data was collected in both the Pechora Delta and Bolshay Synya (Figure 4). Here work was done near the town of Pechora (no. 1), as well as three other sites downstream (3), midstream (2) and upstream (4) of the Synya River. The last site was located within the Yugad-va National Park (http://www.sll.fi/mpe/yugudva/intro.html)

The consecutive year, field work was done in Vel'yu and Upper Pechora (Figure 5). At Vel'yu work was done in a sub-catchment and region where oil exploitation takes place (no.1). Three more sites were visited, on the border of the national park (2; Zapovednik) and two sites within the Zapovednik (3, 4). In addition, a large part of the river was assessed by boat, in particular for landscape and bird observations.

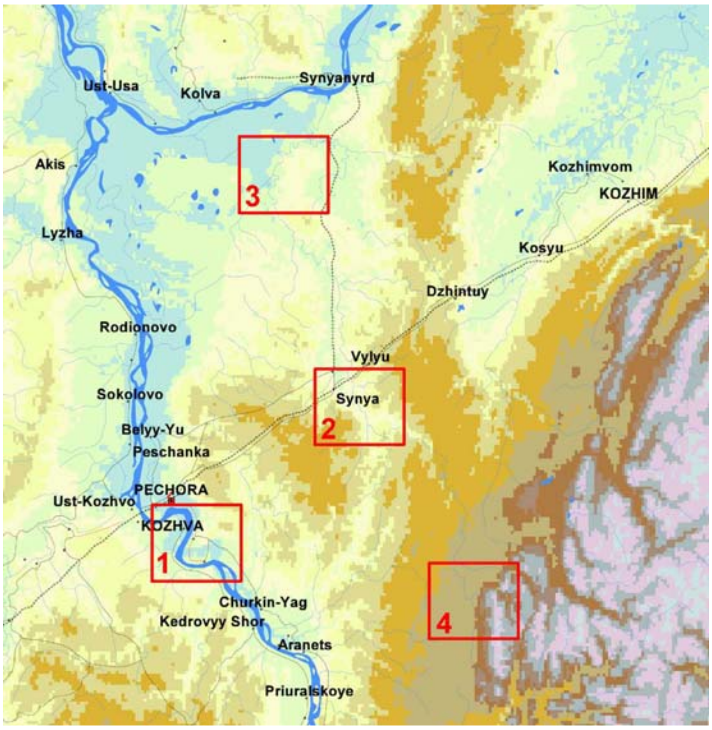

Figure 4: Study sites in 2002 in the Bolshaya Synya sub-area (Leummens et al., 2002).

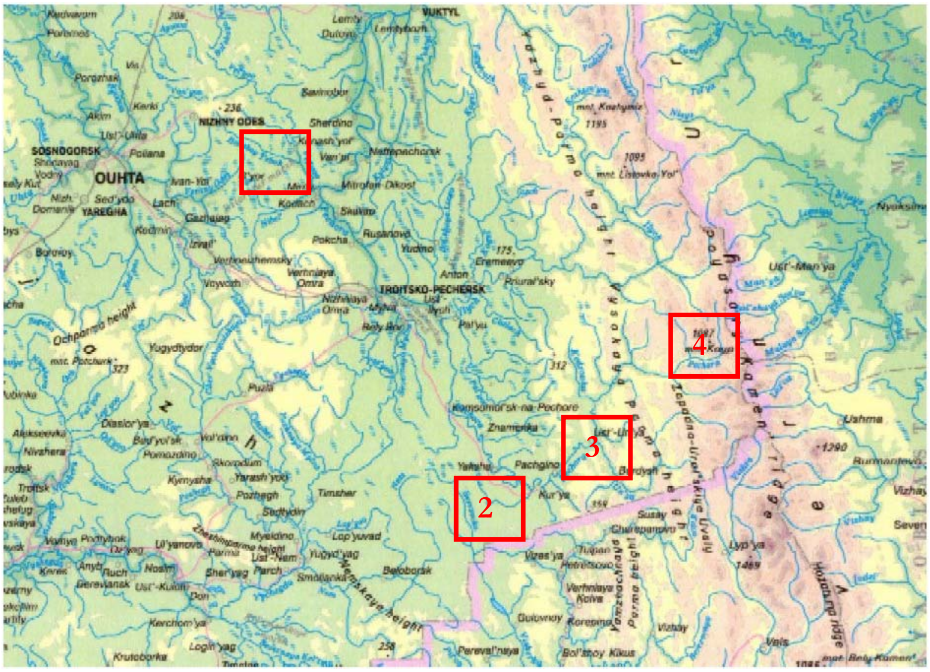

Figure 5: Study sites in 2003 in the Upstream Pechora area (Leummens et al., 2003).

2 What is biodiversity

2.1 Introduction

The assessment of biodiversity is essential to come to effective management of resources, and to comply with international agreements like the Convention on Biodiversity (CBD), ForestFocus and Pan-European Biodiversity and Landscape Diversity Strategy (PEBLDS).

Article 7 of the CBD requires parties to 'identify and monitor components of biological diversity important for its conservation and sustainable use' (Newton & Kapos, 2002). Were in the earlier days inventories geared towards 'stocks', standing volume of wood, or mineral resources, more and more the aim is to ascertain different values and use these data for proper land management. Biodiversity is one of the aspects considered important for monitoring (Newton & Kapos, 2002).

2.2 What is biodiversity?

'Biodiversity' is a contraction of biological diversity. Diversity is a concept, which refers to the range of variation or differences among some set of entities; biological diversity thus refers to variety within the living world (FAO, 2003, Noss, 1999). Biodiversity is the variety of life on Earth, and includes genetics, species, ecosystems and the ecological processes of which they are a part. Biodiversity refers to all living things on Earth (plants, animals and micro-organisms), and to the differences that make each species unique. It takes into account all facets of living beings and their habitats. It is not limited to their biological role and their economic value, but also considers what these species, these landscapes bring to us on educational, cultural, spiritual and aesthetic levels.

It has become a widespread practice to define biodiversity in terms of genes, species and ecosystems, corresponding to the three fundamental and hierarchically related levels of biological organization (WCMC, 1992).

- Genetic diversity: The heritable variation within and between populations of organisms.
- Species diversity: The number of species in a site or habitat. This is also called species richness
- Ecosystem diversity: The diversity of ecosystems. Since there is no unique definition and classification of ecosystems at the global level, it is difficult to assess ecosystem diversity other than on a local or regional basis and then only largely in terms of vegetation.

Noss *et al.* (1997) has outlined a framework of indicators using levels for assessing biodiversity at a national scale:

- Genetic level: Indicators of genetic variation require sophisticated laboratory-based analyses, and are therefore not easily assessed in the field.

- Populations/species level: Biodiversity at populations/species level incorporates demographic parameters (abundance, density, cover or importance value, richness, commonness and rarity etc.) of keystone species or umbrella species, and health parameters. The number of species present in an area could be a measure, to define its ecological value. However, it is an arduous task to list all species of different species groups and taxa. Diversity indices where developed to determine relative diversity of a community.
- Community/ecosystem level: The biodiversity at ecosystem level entails ratios of native to exotic species, species richness, of selected taxa, abundance of groups particularly sensitive to environmental stressors (for example, amphibians, fishes, or butterflies), habitat structure variables, and index of biotic integrity.
- Landscape level: Under biodiversity at landscape level we include factors like the frequency distribution of seral stages (age classes) of sample forests, patch size frequency, patch perimeter, fractal dimension in sample landscapes, fragmentation indices, interpatch distance in sample landscapes, physical connectivity of patches, road density, fire regime (frequency, patch size, intensity, etc.), frequency of major flooding, human population growth, human land-use trends, deforestation, afforestation, total area and distribution of protected areas in various categories, regionally and nationally, and Gross national product (Noss *et al., 19*97).

'Biodiversity has been seen as the total … complexity of all life, including not only the great variety of organisms but also their varying behaviour and interactions. From this viewpoint, no single objective measure of biodiversity is possible, only measures relating to particular purposes or applications.'
(http://www.nhm.ac.uk/science/projects/worldmap/diversity/index.html).

When in research is referred to biodiversity, without any clear definition, the 'species number', or 'species richness' is meant; usually the number of vascular plant species, or bird species. But biodiversity is not just the sum of species numbers for all taxa. Nor can we describe specific ecosystems as having a high biodiversity without defining what is meant by this, since we also find differences between species groups: the important habitats for lichens might differ totally from the areas with high species diversity for birds or mammals (Jonsson & Jonsell, 1999). For PRISM the challenge is therefore to assess whether information of different taxa can be combined in a single biodiversity measure.

There may also be indicator species identified on the basis of their function in an ecosystem, e.g. flagship species or turnstone species, indicator species, umbrella species etc. (Dale *et al., 20*00). Ideally, species with large habitat requirements, 'umbrella species', should be selected to represent all the different forest disturbance regimes and stand types (Uliczka & Angelstam, 2000).
The suitability of species numbers and indicator species will be assessed further in Chapter 3.

The scale level is very important, both for appropriateness of the method and for results of the assessment. Usually α, β, and γ diversity are defined. Alpha (α) diversity is the diversity within a particular area or ecosystem, which is usually expressed by the number of species in that ecosystem. The beta (β) diversity is the species diversity at landscape level, or combined different habitats. The gamma (γ) diversity is a measure of the overall diversity within a large region (Whittaker, 1972).

In this study we mainly focus on the α-diversity, i.e. at ecosystem level, or at a slightly smaller scale, such as 'pine forests', 'lakes' or 'mountain tundra'.

2.3 Why assessing biodiversity

Under the Convention on Biodiversity (CBD) countries are obliged to monitor biodiversity. Monitoring is important to detect ecosystem changes, or effects of e.g. specific restoration measures or air pollution.

The United Nations Development Programme (UNDP) formulated a number of criteria, which should be met by the indicators (see box 1, CBD, 2003).

Indicators should be appropriate for use at a local scale level, but it should be possible to aggregate data to larger scale levels (FAO, 2003). Also the CBD has emphasised the need to adopt the ecosystem approach in indicator development (Newton & Kapos, 2002).

BOX 1: Principles for choosing indicators (CBD 2003)

On individual indicators:

1. Policy relevant and meaningful

Indicators should send a clear message and provide information at a level appropriate for policy and management decision making by assessing changes in the status of biodiversity (or pressures, responses, use or capacity), related to baselines and agreed policy targets if possible.

2. Biodiversity relevant

Indicators should address key properties of biodiversity or related issues as state, pressures, responses, use or capacity.

3. Scientifically sound

Indicators must be based on clearly defined, verifiable and scientifically acceptable data, which are collected using standard methods with known accuracy and precision, or based on traditional knowledge that has been validated in an appropriate way.

4. Broad acceptance

The power of an indicator depends on its broad acceptance. Involvement of the policy makers, and major stakeholders and experts in the development of an indicator is crucial.

5. Affordable monitoring

Indicators should be measurable in an accurate and affordable way and part of a sustainable monitoring system, using determinable baselines and targets for the assessment of improvements and declines.

6. Affordable modelling

Information on cause-effect relationships should be achievable and quantifiable, in order to link pressures, state and response indicators. These relation models enable scenario analyses and are the basis of the ecosystem approach.

7. Sensitive

Indicators should be sensitive to show trends and, where possible, permit distinction between human-induced and natural changes. Indicators should thus be able to detect changes in systems in time frames and on the scales that are relevant to the decisions, but also be robust so that measuring errors do not affect the interpretation. It is important to detect changes before it is too late to correct the problems being detected.

Biodiversity can be assessed in the field, using species data, for plants, or other taxa. Also Remote Sensing can be used, as is done in the BioAssess project (http://www.wsl.ch/land/inventory/remsensing/satellitenfernerkundung/Bioassess/projekt_bioassess.htm; Ivits & Koch, Newton & Kapos, 2002). If you want to assess impacts of certain scenario's models will be required, models which can be based on productivity, disturbance, water availability (Wamelink *et al., 20*03). Also abiotic factors such as temperature, geology, landscape diversity and soil are used (Wohlgemuth, 1998). Wamelink *et al.* (2003) combined management measures with those factors most affected by management: soil acidity, water and nitrogen availability in the application of the model NTM. A biodiversity value was assigned to each relevé on the basis of its conservation value, using the method developed by Hertog & Rijken (1992). In principle this means that every plant species has a value based on its rareness, the temporal trend, and its international rarity, which represents the international responsibility for the species (Hertog & Rijken, 1992).

For PRISM biodiversity is assessed to be able to describe or quantify impacts of certain forest exploitation scenarios. The chosen parameters for biodiversity should be meaningful for the expected or possible changes.

However, also impact of industry, oil and mineral exploitation, infrastructure and land use are important. So indicators should be sensitive to impacts of forestry, hydrological changes, land use changes as well as pollution and fragmentation.

Since these factors operate at local scale level, and sometimes at landscape level, the α and β diversity are most relevant for PRISM. The indicator should be used for the land units as defined, e.g for bogs, forests, tundra etc.

2.4 Components of biodiversity

Despite the wider meaning of 'biodiversity', the definition often used is the number of species in a site. This narrow definition might result in high biodiversity values for disturbed areas (e.g. gardens, with ruderal species and neophytes), and low biodiversity for species-poor ecosystems such as peatlands or even some pristine forests. Therefore it is considered important to use the wider definition of ecosystem biodiversity.

Many aspects are in general considered important for biodiversity, or conservation value. Table 1 presents indicators generally used for biodiversity. The total of 23 indicators shows the wide range of what is regarded as being important.

It may be clear that in contemporary biodiversity assessment research many more parameters are in use. A recent study of the European Environment Agency shows a total of 655 indicators for biodiversity, of which 78 should be relevant for forestry, and 387 for nature protection (EEA, 2004).

Some of these parameters have been proposed but have never been brought into practice, others may be appropriate only at specific scale levels, or different ecosystems.

It is imperative that in this study we must be selective, and use those indicators which may be meaningful, and which are commonly accepted as indicator. In this study a number of indicators are selected, and tested on its usefulness and appropriateness, to come to a final proposal for biodiversity assessment. The method is tested and developed for boreal forests in Northwest Europe and Russia. It would be of interest to test whether this approach would suit also Nordic countries or Canada.

Table 1: Used criteria to determine conservation value of areas. (De Groot, 1992, modified after Margules & Usher, 1981, and Spellerberg, 1992).

Criteria	Relative importance*	ranking	Relative importance**	ranking
Diversity (of species and/or habitat /only species)	12,2	1	18,1	1
Rarity (of species and/ or habitat)	11,3	2	9,2	4
Representativeness	10,2	3	2,5	11
Area size needs/minimum critical ecosystem size	9,9	4	1,3	13
Naturalness/heritage value	8,9	5	8,1	6
Scientific value	8,4	6	-	-
Ecological fragility/species vulnerability	8,3	7	2,5	11
Uniqueness/endemicity	8,0	8	-	-
Threat of human inference	8,0	9	11,2	3
Wildlife reservoir potential	7,4	10	-	-
Potential value	5,0	11	3,3	10
Management factors	4,8	12	0,7	15
Position in ecological geographical unit	4,7	13	4,0	8
Replaceability	3,8	14	13,1	2
Amenity value/aesthetic qualities	2,8	15	-	-
Record history	2,0	16	0,8	14
Education value	1,5	17	-	-
Availability	0,7	18	-	-
Special environmental conditions	-	-	0,7	15
Maturity	-	-	9,0	5
Completeness	-	-	4,5	7
Protection function for abiotic factors	-	-	0,7	15
Synecological importance	-	-	4,0	8

* The importance of values calculated are based on Margules & Usher (1981) using the Delphi-method.

** Weighting in 20 analysed assessment methods for areas (biotopes), which were within impact regulation in Germany.

2.5 Different biodiversity assessment approaches

Different combinations and weighting of criteria were compounded to a 'total value' for conservation which, leads to widely differing evaluation results between different authors. This has also been a main criticism for this approach (Spellerberg, 1992). If, however, the same approach is applied for comparison of areas it can be very informative, and more meaningful though, as is shown in regional applications (e.g. Clausman *et al.*, 1984, Hertog & Rijken, 1992).

An informative website from the Natural History Museum (UK) describes the options for Biodiversity evaluation (http://www.nhm.ac.uk/science/projects/

worldmap/index.html). It stresses the relevance of 'single currency' approach, instead of compounded measures.

The following paragraphs present in particular indicators used for forest management and biodiversity monitoring.

2.5.1 Quantititative indicators for forest management

For forest management a number of accepted indicators has been confirmed by the Ministerial Conference on the Protection of Forests in Europe (MCPFE). The most recent Ministerial Conference was held in Vienna, 2003 (the 'Living forests summit'), where one of the resolutions (V4) was: conserving and enhancing forest biological diversity in Europe (www.mcpfe.org). The group of experts has worked out the resolutions into indicators (Table 2).

Table 2: Indicators as used by the Ministerial Conference on the Protection of Forests in Europe (www.mcpfe.org).

Indicator	Relevance PRISM
Tree species composition	
Regeneration	
Naturalness	√
Introduced tree species	
Deadwood	√
Genetic resources	
Landscape pattern	
Threatened forest species	√
Protected forests	

Not all of these indicators might be useful for the aims we have in the PRISM project, some are difficult to assess. In particular 'naturalness', 'presence of dead wood' and 'threatened forest species' (e.g. Pinus siberica) are relevant.

2.5.2 Global Forest Resource Assessment

The Global Forest Resource Assessment 2000 used key indicators to assess status and trends in forest biological diversity, relating in particular to the naturalness, protection status and fragmentation of forests. Also statistics were used, e.g. area of different forest types, protected areas, but also the number of endemic and threatened species for seven species groups (FAO, 2000).
Not only forest quantity, but also forest quality was assessed (Newton & Kapos, 2002).

2.5.3 Indicator species for biodiversity monitoring

To describe the complex system of biodiversity, simplified parameters like indicator species are often used (Noss, 1990).
The concept of indicator species is still debated: because indicators of biodiversity have been poorly tested. Proper validation is required in order to come to valid interpretations (Noss, 1999).
Certain species are capable of expressing characteristics that can indicate the state of the ecosystem they currently occupy. They can be indicative for e.g. (absence of) pollution, but there are also indicators for specific habitat qualities like large intact forest systems such as the Three-toed woodpecker (*Picoides tridactylus*) (http://www.uec-utah.org/help/MIS%20TES/uinta%20mis%20tes.htm).

For the World Conservation Monitoring Programme (WCMP), a set of indicators for biodiversity is developed with the aim of revealing trends in biodiversity. The indicators are based on indicator species that are selected for main ecosystem types (De Heer, in press). One of these ecosystem types is the boreal forest, but also for aquatic ecosystems or peatlands indicators are developed.
The indicator species have not been extensively tested so far.

Table 3: Indicator species WCMC for different ecoregions (De Heer et al. in press).

	Butterflies	Birds	Mammals
Woodland & forest habitat	Carterocephalus silvicola Erebia ligea Euphydryas maturna Gonepteryx rhamni Leptidea sinapis complex Limenitis populi Lopinga achine Melitaea athalia Nymphalis antiopa Pararge aegeria	Bobycilla garrulous Bonasa bonasia Certhia familiaris Dendrocopus leucotos Dendrocopus minor Dryocopus martius Ficedula hypoleuca Nucifraga caryocatactes Parus cinctus Parus cristatus Parus palustris Perisoreus infaustus Pernis apivorus Phoenicurus phoenicurus Phylloscopus sibilatrix Picoides trydactylus Picus canus Sitta europaea Tetrao urogallus	Alces alces Canis lupus Cervus elaphus Lynx lynx Rangifer tarandus Ursus arctos
Farmland	Aglais urticae Inachis io Lycaena phlaeas Papilio machaon Pieris brassicae Pieris rapae Vanessa atalanta	Alauda arvensis Coturnix coturnix Emberiza citrinella Motacilla flava Passer montanus Perdix perdix Vanellus vanellus	

In some cases species rarity has been combined with the distribution area of the species and the trend, or species as indicator of the quality of ecosystems (Reijnen, 1998, Ten Brink *et al., 20*02). The problem in this approach is, however, in defining the reference state of a species. For less well-known species, or species which were very common some decades back, this may pose serious problems. If the '0-state' is not known, it is not possible to define the trend in an accurate manner.

2.6 Conclusions

It is shown that the concept of biodiversity is rather new. It is applied in many different ways, in different contexts, often without indicating what is meant with biodiversity. This chapter shows the general implications of biodiversity, and how it is used, for management or policy development.

Criteria for use of indicators as they were developed by the Convention on Biodiversity are presented in Box 1. In Table 1 the important indicators for conservation are presented, which should be most leading for the choice of biodiversity parameters for PRIMS (chapter 3). An overview of assessments for forestry and biodiversity monitoring is presented in 2.5, and in particular naturalness, deadwood and the number of (threatened and endemic) species is important. It may be tested whether the known indicator species can be of use for PRISM too. The (geographically) limited number of sampled areas and the extent of the study area does not justify the development of a specific set of indicators for (high) biodiversity or undisturbed areas in Pechora at this moment.

3 Choice of biodiversity parameters

3.1 Introduction

For the PRISM project biodiversity parameters have been selected, based on their relevance for boreal forests (pristine and managed), the interventions which are foreseen in land use (which may include oil and gas exploitation) and forest exploitation, and the field data that has been collected. The following indicators are proposed for assessment of the 'biological diversity':

At landscape/ecosystem level:

- ecosystem rarity (e.g. number of rare or endemic species)
- landscape pattern (minimum critical ecosystem size)
- naturalness
- representativeness
- ecosystem processes

At stand level, or local level:

- indicator species
- species diversity
- species rarity (e.g. number of Red List, rare, protected or endemic species)
- dead wood
- structural diversity

3.2 Indicators at landscape level

Ecosystem rarity

Rarity or uniqueness of an ecosystem or species is an important attribute for biodiversity. Ecosystem uniqueness can be assessed by the mean level of endemism of various taxonomic groups. Another measure is the share of an ecosystem type in the total surface area.
Only the latter approach may be useful for the PRISM project, since existing data is insufficient for the first approach.

Minimum area size / Landscape Pattern (minimum critical ecosystem size)

Each natural community or ecosystem requires a minimum amount of space, to maintain its diversity and to function properly. The size of an area therefore is of critical importance for its functioning as protected area (McArthur & Wilson, 1967). Reserves that are too small can never support the full range of species that might be considered as part of the ecosystem. Besides, if the area is limited or if the carrying capacity is low, populations are too small to be sustainable (Groot Bruinderink *et al.*, 2003).

The concept of minimum area size and effects of fragmentation is quite European, which has to do with the period of land transformation and the effects it has on biodiversity. Also the settlement history and population densities of Western Europe may have contributed in the development of this concept. Despite this, fragmentation may have important bearings on boreal forest conservation, and for that reason it is discussed here. Studies in Sweden and Finland show that species diversity might increase with the age of the forest. However, in some cases where forest fragments were less than 20 ha in size it was argued that the absence of these species might be due to fragmentation, since in similar areas in more intact landscapes specific indicator species like three-toed woodpecker or grey-headed woodpeckers (*Picus canus*) are present (Uliczka & Angelstam, 2000).

Most common parameter for fragmentation or landscape pattern are landscape matrices, or indices, calculated with GIS-software e.g. Fragstats (McGarigal & Marks, 1995). However, like for every index, these indices are of little value as long as there is no proper relationship with specific species and species requirements.

For plant and animal species threshold values can be derived from ecological research. Based on empirical evidence it can be established what the Minimum Viable Population size is, i.e. the size for which chances of extinction are less than 5% in 100 years (Hunter, 1996, Shaffer, 1981, Foppen, 2001).

Habitat modelling is one of the options to define those areas which are fragmented, and areas that are well connected and suitable for species or species groups (or indicator or umbrella species). The model LARCH assesses fragmentation and habitat suitability, and was applied in many different environments and geographical regions (Van der Sluis *et al., 20*01, 2003), but also simpler rule-based habitat modelling is possible.

At this stage it is not yet feasible to implement a measure for area size or landscape pattern, because data and digital maps available do not permit a good analysis of the fragmentation pattern.

Naturalness

The naturalness of boreal forests are in particular linked to scale, process and composition of the forests (Table 4). Naturalness of a site can be narrowly linked to species diversity. Species numbers tend to increase after disturbance of (virgin) forest ecosystems, due to a different light regime and an increase in available (disturbed) habitat. We might see therefore e.g. an increase in vascular plant species, bird, insect and invertebrate species. On the other hand, some species groups clearly show a preference for undisturbed situations, in particular dead wood fauna, cryptogamic species and large mammals (Wohlgemuth *et al.*, 2002).

Table 4: Characteristics of natural forests (Angelstam et al., 1997).

Characteristics
old-growth forests and large old trees
diversified tree species composition
dead, standing, and down trees
undrained forests
unregulated rivers
balanced natural processes (browsing, predation, nutrient supply

The naturalness of an area depends on the degree of human presence, either in terms of physical, chemical or biological disturbance (De Groot, 1992). The degree of naturalness can be described by the degree of human impact, e.g. percentage surface area converted, or pollution level. A widely accepted criterion for a 'natural ecosystem' is 'an ecosystem where since the industrial revolution (1750) human impact has been no greater than that of any other native species, and has not affected the ecosystem's structure' (IUCN, UNEP & WWF, 1991). This is further worked out, with different degrees of human influence, in Spellerberg (1992). This, however, is not the case in the Pechora River Basin.

In the Ministerial Conference on the Protection of Forests in Europe (MCPFE) (www.mcpfe.org) naturalness has been described in three classes:

- undisturbed by man
- semi natural
- plantations

Elsewhere, up to five classes were used in highly modified environments, being: natural or near natural conditions, semi-natural landscape without parcels, semi-natural with parcels, cultural landscape, urban landscape (Londo & Wirdum, 1994).

Newton & Kapos (2002) suggest using the tree stumps per site as indicator of disturbance (high, medium or low timber extraction levels).

Recently a more detailed assessment was proposed with a nominal scale, ranging from 0, minimum of naturalness, to 10, maximum naturalness (Machado, 2004). His assessment is based on aspects of natural elements, energy, physical alteration and fragmentation.

Representativeness

Representativeness does refer to the fact that a reserve should contain biota which represents the range of variation found within some land class or region (Usher, 1986). The concept might have been introduced under the Man and Biosphere (MAB) program (http://www.unesco.org/mab/), where the aim of the biosphere reserves was to represent the range of global biotic provinces.

This parameter may be more appropriate for reserve design, and is less suitable for the PRISM project.

Ecosystem processes

The ecosystem processes are crucial for maintenance of biodiversity (Huston, 1994). It is also identified in the CBD as one of the reasons to protect complete ecosystems, so that also these processes are guaranteed (Jenkins & Williamson, 2003).

Wohlgemuth *et al.* (2002) consider disturbance as the most important factor for biodiversity and species richness. Disturbance is divided into three aspects, namely endogenous (gradual), exogenous (episodic) and human induced (periodic). The latter is of course closely related to the degree of naturalness, discussed above. The impact of those disturbances differs for e.g. alpha (α) and gamma (γ) diversity, but also in spatial extent, intensity and frequency.

Main processes or disturbance factors relevant for boreal forests are shown in Table 5:

Table 5: Natural processes in main forest types in Central and Northern Europe; X = very important, x = less important (Angelstam et al., 1997).

Disturbance	Forest type Boreal	Temperate lowland	Riparian
Fire	X	x	-
Flooding	-	-	X
Gap phase	x	X	X
Browsing	x	x	-
Grazing	-	x	x
Wind	x	x	x
Beaver	-	-	x

The connotation that goes with the presentation of the disturbance as a factor in the paper (Angelstam et al., 1997) is that management of disturbance can be an effective tool to optimise species diversity. Due to disturbances, dominance reduction might occur, resulting in higher species diversity (Table 6, Wohlgemuth, 2002).

Table 6: Categories of disturbance and their effects on forest ecosystems in Central Europe (Wohlgemuth, 2002)

Disturbance types	Cause	Examples	Disturbance regime			Effects on species			
			Spatial extent	Intensity	Frequency	Dominance	Ecological groups	α-Diversity	ζ-Diversity
Endogenous (gradual)	Forces inside a stand	Aging and decay, resulting in gaps, moderate game pressure	Small	Low	High	Reduction or increase depending on gap size	Maintains continuity demanding species	Small contribution	Large contribution
Exogenous (episodic)	Forces outside a stand	Wind, fire, avalanches, flooding, landslides, pests	Potentially large	High	Low	Often reduces dominance	Maintains light demanding species	Large contribution	Small contribution
Human-induced (periodic)	Human activities	Forest management (cutting, planting), pasture, collecting of firewood, litter and other forest products	Highly variable	Highly variable	Highly variable	Highly variable	Highly variable	Highly variable	Highly variable

3.3 Indicators at stand level or local level

Indicator species

Although it is acknowledged that it is impossible to assess all species and taxa to come to an estimate of biodiversity, there is still thorough research required to ascertain that a given species is indicator of a certain aspect or characteristic of the taxon studied (Newton & Kapos, 2002). Understanding of the response of one species won't provide a reliable prediction for other species of a similar group, despite the fact they may seem very similar (Lindenmayer, 1999). Indicator relationships can be weak, absent or even negative (Jonsson & Jonsell, 1999, http://www.nhm.ac.uk/science/projects/worldmap/index.html).

In addition, indicators are operative in a certain area or range, and might not do so elsewhere. Also, spatial and temporal scales differ much, so an indicator species

might not act as other species would, due to different requirements in this respect (Lindenmayer, 1999).
It was shown that e.g. floristic species (vascular plants and lichens) were more indicative of forest composition, whereas bird diversity would increase with the age of the forest. The implication is that different taxa can be indicative for different aspects of the forest (Uliczka & Angelstam, 2000). Occurrence of specific lichens such as *Lobaria pulmonaria* is indicative for Red List beetle species, so such a species is indicative for key-biotopes (Uliczka & Angelstam, 2000).

Species richness, species diversity
Species richness, or species diversity, which terms are often exchanged, means the number of a species in a site, a landscape or ecosystem (see also § 2.2). Species richness is usually applied in the sense that high species diversity is regarded as better and maximum species-richness is the most important management goal (Attiwell, 1994, in Lindenmayer, 1999). However, we observe here that high species richness is often associated with harvesting activities, due to invasion of plant and bird species in open vegetation (Wohlgemuth *et al., 20*02). In other ecosystems we observe high 'biodiversity values' for disturbed areas (e.g. gardens, with ruderal species and neophytes), and low biodiversity for species-poor ecosystems such as peatlands or even some pristine forests. Species that depend on intact forest ecosystems may well disappear in such a dynamic situation, and in particular rare species might be absent despite the high species diversity (Lindenmayer, 1999, Wohlgemuth *et al., 20*02). Species richness assessed at a scale exceeding local stand level might be reduced in these situations. It also shows that species richness is very much dependent on scale and time. Finally, species diversity may mask important changes in community assemblages.

Also special indices are used to describe species diversity. Diversity indices can provide important information about rarity and commonness of species in a community, (i.e., they account for some species being rare and others being common). The ability to quantify diversity in this way is a valuable tool to compare diversity in different communities and describe its numerical structure.
The simplest index is Simpson's diversity index, which take care of both abundance (and biomass), and species richness.

Simpson's diversity index (*D*) is a simple mathematical measure that characterizes species diversity in a community (Simpson, 1949, Begon & Harper, 1986). The proportion of species *i* relative to the total number of species (p_i) is calculated and squared. The squared proportions for all the species are summed, and the reciprocal is taken:

$$D = \frac{1}{\sum_{i=1}^{s} p_i^{2}}$$

For a given richness (*S*), *D* increases as equitability increases, and for a given equitability *D* increases as richness increases.

Shannon-Weaver's diversity index is also widely used (Huston, 1994). This index uses both abundance and number of species present. Higher values are obtained in communities with many species, evenly distributed. The proportion of species i relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by -1:

$$H = -\sum_{j=1}^{S} p_i \ln p_i$$

The Shannon-Weaver and Simpsons diversity indices for a community will increase when species richness is higher, however this increase in far less than with the species richness index and is influenced by the distribution of individuals among the species. A more even distribution gives a higher value for the Shannon than for the Simpson index. In practice it seems that the Simpson index is slightly less influenced by species richness than Shannon's diversity index.

The *evenness* or *equitability* is a value that comes with both of these indices and describes the distribution of individuals in the community among the species. It is calculated by dividing H or D, by respectively H_{max} or D_{max}. Equitability assumes a value between 0 and 1 with 1 being complete evenness.

Species rarity

The number of rare or endemic species is a measure of rarity. Rare species are the Red List species, or species that are under threat. In the study area a number of endemic and Red List species occur.

Rarity can be based on range-size (Welk, 2002) as well as density (http://www.nhm.ac.uk/science/projects/worldmap/index.html). Endemism might be a specific form of rarity, for species restricted to particular areas with a prescribed extent. Red List species are –according to the criteria of the IUCN- defined on the basis of rarity and the trend of decrease. If data are lacking, lists are compiled on the basis of expert knowledge. As a result, some species are on the Red List because they are at the border of their distribution area and/or with a general low abundance. An example is *Salamandrella keyserlingii*, which has a large distribution area from Japan to Central Russia, the species is not rare or threatened but occurs in Russia in low densities and is therefore included in the list (Kuzmin, 1995).

There are some 20 endemic vascular plant species in the Pechora Basin (S. Degteva, Institute of Biology Syktyvkar, pers. comm.). Tables present the Red List species for the Komi Republic. Data are derived from distribution maps of the Komi Red Data book (Taskaev, 1998). The All Russian Red List species are found on internet as well: http://www.grida.no/enrin/biodiv/biodiv/national/russia/index.htm.

Table 7: Red List species and endemic species occurring in the Pechora River Basin (? indicates status unknown, - indicates none), based on Taskaev (1998).

Per site:	Vascular plants	Lichens	Mosses	Birds	Mammals	Fishes	Insects	Herpeto-fauna
Red List species	16	65	71	34	11	5?	40?	1
Endemic species	20	?	-	-	-	?	?	-
Rare species	172	24[1]						

Dead wood

In many assessments and evaluations dead wood is seen as an important indicator for biodiversity. Many species are dependent on dead wood, and its presence means therefore additional diversity in the ecosystem. Dead wood might also indicate more extensive management practices or no management at all, with associated higher biodiversity. There are many different approaches in assessment of dead wood (see e.g. Ståhl & Lämås, 1996).

Structural diversity

Structural diversity is used in particular for forests. The structural complexity of a certain site may determine habitat availability, and thus the diversity of plant, animal and microbal communities (Ferrris & Humphrey, in Newton & Kapos, 2002). It is hard though to assess in a standardized way the structure of a forest.

3.4 Conclusion

Suitable indicators are selected, based on the importance for PRISM and the possible practical application.

Proposed indicators at landscape/ecosystem level are: ecosystem rarity, landscape pattern, naturalness, representativeness, and ecosystem processes.

At stand level or local level, relevant possible indicators are: indicator species, species diversity (both species richness and diversity indices), and species rarity.

4 Results biodiversity assessment regional level

4.1 Introduction

We used several indicators discussed and selected in § 3.4 to describe the biodiversity of the Pechora River Basin. In this chapter the biodiversity results are presented, based on field data gathered in the framework of this project (Leummens *et al., 20*02, 2003). These results are therefore at a regional level, based on own observations. The observations in this Chapter are discussed based on the Land units, as they are described in Appendix 1.
In the following chapter (5) an analysis is done of indicators at river basin level (see also § 3.2).

In addition to these indicators, an analysis was done on a selection of samples for which the disturbance factor was known or could be derived. An analysis of the 'naturalness' or 'disturbance' for those samples, can show the correlation between naturalness and the biodiversity indices.

4.2 Data collection and processing

During 2002 and 2003 data has been gathered on the abundance of plant and animal species in the Pechora River Basin (Leummens *et al., 20*02, 2003). This has resulted in a large database with information on vegetation cover (vascular plants, lichens, and mosses), insects, mammals, birds, herpetofauna (amphibian and reptile species), fish and benthos. The data is linked to a land classification unit that describes the landscape at three different scale levels, each suitable for different species ecological analysis (Appendix 1). E.g. forest is divided in seven different types; one of them is spruce/fir forest, which is subdivided into four subtypes, based on moss or dwarf shrub ground cover.

Vegetation descriptions have been prepared according to a generally accepted and standardized method, which makes them ideal for an objective comparison. The sample area has a fixed size for different vegetation formations (forest plots are 20 x 20 m., grassland 10 x 10 m). For each species the abundance is estimated according to the so called 'Ipatov scale', which is a relative measure of vegetation cover (Degteva, 2004).
The collected data on plants (vascular plants, mosses and lichens) has been stored in TURBOVEG (Hennekens, 1995, Hennekens & Schaminée, 2001). In TURBOVEG the species richness, Shannon-Weaver and Simpson's diversity index and evenness can be calculated in a standard procedure.

Different methods have been used to collect abundance data on *mammals*. Transects with small rodent traps were used, which were checked twice a day during a 4-days period. Furthermore incidental observations were done during field work, mammal tracks were recorded, and dung was identified or collected.

For *birds* point observations were made, and observations were done (mostly) along transects. Transects ranged from 120 m (by foot) upto 70 km (by car and boat). In order to make the data comparable, it has to be synchronised. In the case of bird observations, only the transect data were used for the analysis, but they were generalised to the number of birds per 100 m of transect. For birds' species richness and number of Red List species all collected data was used.
For the Pechora delta region data have been obtained on breeding birds, fishes, vascular plants, lichens, mosses, and insects in five seasons, 1996-2000 (Van Eerden, 2000). In the current report bird data have been adjusted for re-analysis in order to assess biodiversity in the Delta region as well.

Fish data were collected by fishing rod, electro-fishing, gillnets, and dragnets (Ponomarev *et al., 20*04). In addition visual observations were recorded. All samples taken by nets are compared in order to make a quantitative comparison of fish species in the different Land Units.

Insects were sampled through sampling, sampling by net (butterflies, dragonflies, stoneflies), soil litter samples (terrestrial meso- and macrofauna), soil traps (beetles, spiders), and window traps (beetles) (Kolesnikova & Van der Sluis, in prep). For the analysis soil traps and soil litter samples were compared. For insects an analysis was done on species as well as on family.
The abundance of insect species was recorded using the code E, R, U, A (resp. single individual, rare, usual/common, abundant). In order to compare the data statistically, these codes were converted into numbers E=1, R=3, U=10, A=20.

Benthos data were collected through samples taken of the river bottom. These samples were equal in size and could thus be safely analysed without further adjustments. An analysis was done on genus as well as on species level.

If exact values were missing in the database, the observation was not used for the analysis of e.g. diversity indices, but it was still used for species richness or Red List species analysis. For instance in the fish database the missing number for Nine-spined stickleback *(Pungitius pungitius*) is given value one, rather then leaving it out of the data set, in order to take it's occurrence into account.

A first attempt was made to analyse the correlation between terrestrial species diversity and disturbance. A selection was made of all spruce/fir forest vegetation samples. Approximately half of the forest descriptions (32 of the total of 71) contained information on forest management regimes or evidence of natural or anthropogenic fire. Because of the small number of samples of spruce forests, a wider selection of all forests was taken, in total 185 samples of which 91 contained information on disturbance (Appendix 5: Disturbance class per relevee). The rate of disturbance varies from undisturbed to selective cutting and tracks of fire, which was described into 4 classes of naturalness. Class 1 means undisturbed forest; class 4 means much disturbed, for example where selective cutting or clearcut harvesting was done.

4.3 Indicator species

Of the selected indicator species from the World Conservation Monitoring Centre WCMC (§ 2.5.3) 4 mammals species (out of 6) were observed in the PRISM biodiversity assessment (Figure 6): Elk (*Alces alces*), Wolf (*Canis lupus*), Reindeer (*Rangifer tarandus*) and Brown bear (*Ursus arctos*). Small mammal species are under represented in the WCMC list; the selection may therefore be limited.

Most observations (3) were done in spruce forest (FS) and disturbed (burnt) forest (FDb; see Appendix 1 for the land unit codes). Not all land units were equally well sampled, which is also due to the location of the sampled areas.

Some 13 bird species, out of a total selection of 19 (see § 2.5.3) were observed during field work (Figure 7). Most observations (55) were done in aquatic riverine habitat (WRm). Otherwise, most observations were done in Spruce forest (FSg, FSh) and mixed forest of spruce type (FMs).

Most frequently observed were the Nutcracker (*Nucifraga caryocatactes*), Bohemian waxwing (*Bombycilla garrulus*) and Common redstart (*Phoenicurus phoenicurus*).

Of the 10 butterfly indicator species selected for boreal forests, 4 species were observed during fieldwork (Figure 8). Most observations were done in unit WGn, natural grasslands of the floodplain, two species were observed here. Along floodplains and river bank (WSg), abandoned meadows (AGa), haymeadows (AGh) and mixed birch forest (FMb) many butterflies were observed.

The highest number of species (3) was observed in haymeadows (AGh) and mixed spruce forest (FMs). The species *Carterocephalus servicolus* was observed in almost all different land units, so it may not be very indicative for boreal forests.

4.4 Species richness

Species richness has been assessed by calculating the species number per Land Unit, by defining Shannon-Weaver's and Simpson's diversity index, and species evenness.

Not all data is suitable for diversity indices, in fact only the vascular plants and lichens were in a similar method sampled, so that Land Units are well characterised with this data.

For mosses the data may not be representative enough, and outcome may therefore not be reliable. Bird data was afterwards linked to a specific Land Unit type and density per sampling effort (observations per 100 m) was used for diversity indices. For the herpetofauna and mammals the number of species and observations were too limited to define densities, therefore no diversity indices could be calculated.

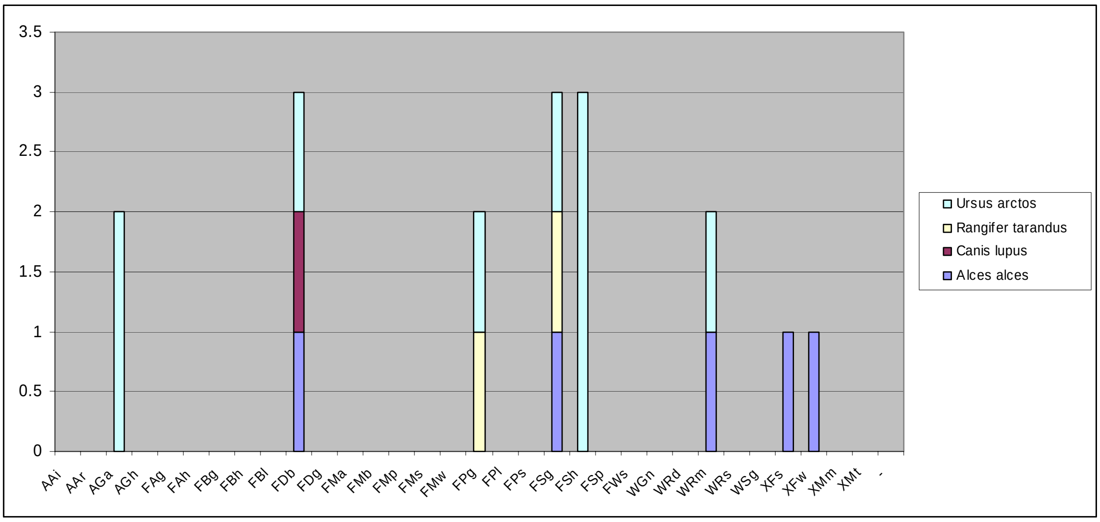

Figure 6: Observations of mammal indicator species for boreal forests (selection WCMC, Table 3).

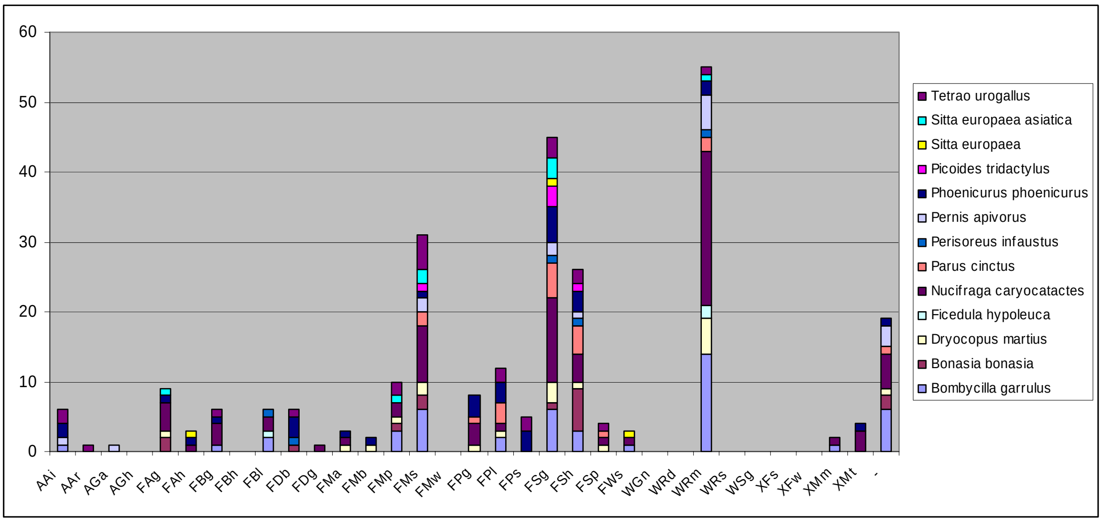

Figure 7: Observations of bird indicator species for boreal forests (selection WCMC, Table 3).

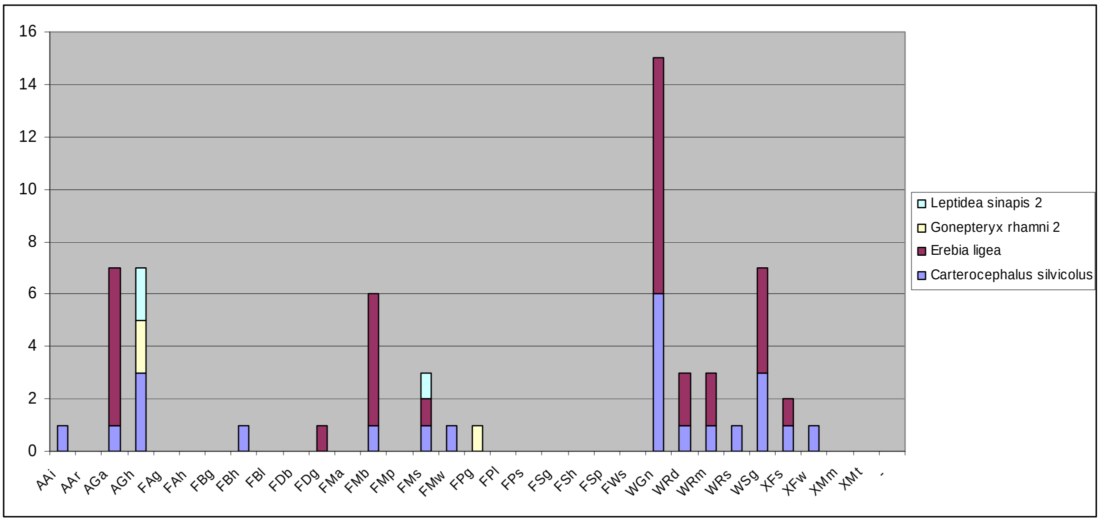

Figure 8: Observations of butterfly indicator species for boreal forests (selection WCMC, Table 3).

Table 8: Species richness and diversity indices defined for species groups.

Per site:	Vascular plants	lichens	mosses	birds	mammals	herpetofauna	insects	fish	benthos
Species richness	yes	yes	yes	yes	yes	yes	yes	yes	yes
Shannon's DI	yes	yes	yes	yes	-	-	yes	yes	yes
Simpson's DI	yes	yes	yes	yes	-	-	yes	yes	yes
Species eveness	yes	yes	yes	yes	-	-	yes	yes	yes

The results for species richness can be found in appendix 4. The results may sometimes be biased, due to an unevenly distributed sampling effort – and some Land Units were not covered at all, due to logistic problems and the enormous size of the river basin.

Appendix 4 shows all the calculated diversity indices per Land Unit. Table 9 shows a more generalised result: here all observations of e.g. Spruce forest (FSh, FSg, FSp, FSs) are combined for general Spruce forest (FS). In Figure 9, 10, 11 and 12 the charts of the diversity indices for resp. vascular plants, birds, insects (genus level) and fish are presented.

Some Land Units are more species rich then others, which is of course not the same for each species group. Anthropogenic (disturbed) habitats are in particular species rich in birds and herpetofauna (amphibians mainly). Grasslands are generally species rich in insects and vascular plants. Considering all forests, irrespective of the type, these are in particular species rich in birds, mammals, vascular plants, lichens and mosses. More specific, Birch forest is rich in insects and vascular plant species, whereas mixed forests are rich in bird and lichen species. Spruce forests are rich in birds, mammals, insects, vascular plants, mosses and lichens. Aquatic and riverine habitats are species rich for birds, fish and benthos. Riverine grasslands are very rich in vascular plants, whereas fens and bogs contribute in mosses and herpetofauna richness, and mountain habitats in particular for lichen species.
The species richness for vascular plants and insects can probably be explained from light conditions, and related with that the humus layer.

The Shannon's diversity index is for birds highest in clearcut forests (FDi), and mixed forests FM (aspen and birch dominated), Riverine grassland (WRm) and open mountain forest mosaic (XMm). These are all either dynamic or more open vegetation types. Except for WRM they were all sampled once (or as one transect). Insects have especially a high Shannon's diversity index in Spruce forests (FS) and mixed forests of spruce type (FMs). These units are intensively sampled as well.
Fish and benthos reach high values in rivers, in the main stream (WRm), but benthos also in small streams and creeks (WRs) where values for fish were particularly low.
Vascular plants, lichens and to a lesser extent mosses have rather evenly distributed Shannon diversity values.

Simpson's diversity values are strikingly low for the vegetation. For the other species groups the results are rather similar compared to Shannon's diversity index.

A summary table for vascular plant diversity, at a higher aggregation level, (Table 9) shows high diversity values for grasslands (AG and WG), as well as for aspen, birch and willow forest. Also here a relation may exist with light conditions and humus layer. Spruce forest (FS) has not the highest (average) species richness, but the maximum number of species (64) was observed among the spruce forest and natural riverine grasslands.

Table 9: Summary table for vascular plant diversity, including max. species richness; marked are high values.

	AA	AG	FA	FB	FD	FM	FP	FS	FW	W	WG	XF	XM
# samples	16	10	5	38	19	5	28	72	20	18	16	32	11
Richness	25.81	42.70	34.00	31.89	18.16	28.20	13.54	27.72	40.15	25.78	41.94	15.06	25.64
Max. spec. richness	46	61	47	56	32	45	39	56	64	58	64	39	41
Shannon	2.06	3.08	2.22	2.15	1.74	2.00	1.39	2.01	2.27	1.84	2.72	1.65	1.89
Evenness	0.65	0.83	0.63	0.64	0.61	0.61	0.55	0.62	0.62	0.60	0.73	0.63	0.59
Simpson	0.76	0.87	0.82	0.79	0.73	0.78	0.63	0.75	0.77	0.65	0.84	0.70	0.75

The species richness for vascular plant species (all relevees; Appendix 4) may differ from 4 to 126 species. Per Land Unit it may range from 15 to 116.
Vascular *plants* clearly have the highest species richness and diversity indices in haymeadows (AGh). Other important Land Units are grazed meadows (AGg), aspen forest of herb type (FAh), birch forest of herb type (FBh), spruce forest of herb type (FSh), natural grassland (WGn), sandbanks (WSs) and tall sedge marsh (XFf) (Figure 9).

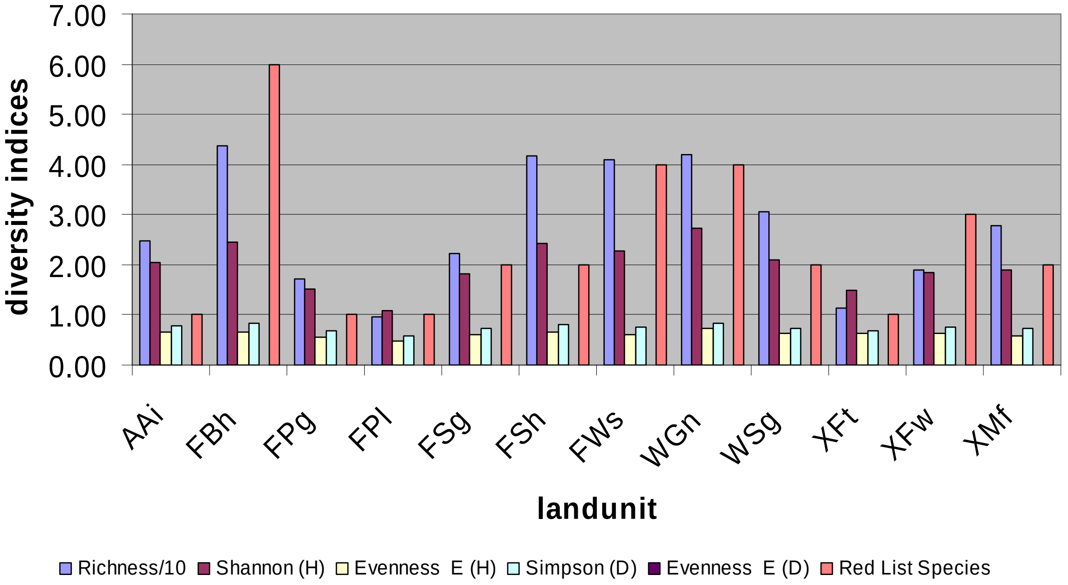

Figure 9: Diversity indices for vascular plants (selected units).

For *birds* the most species rich Land Units are found along infrastructural works (AAi), (AGa), Aspen forest (FAh), clearcut (FDi), Mixed (birch) forest (FMb), (FMs) and main rivers (WRm) (Appendix 2, Figure 10).

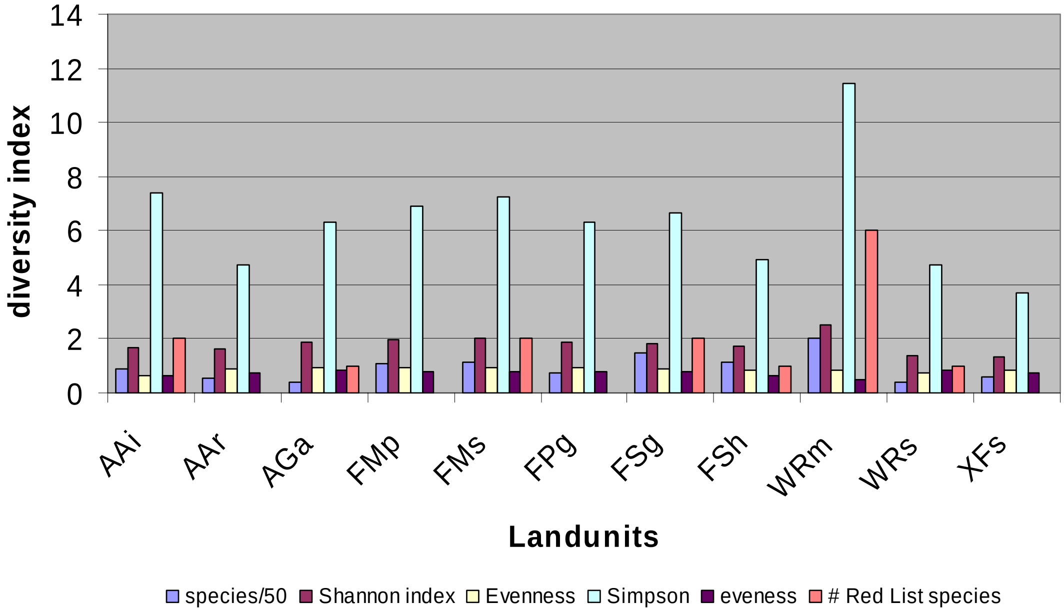

Figure 10: Diversity indices for birds (selected units).

For *insects* spruce/fir forest (FSs) is most rich in insect groups, but also birch forest of herb type (FBh), as well as clearcut (FDg), and mixed (spruce) forest (FMs).

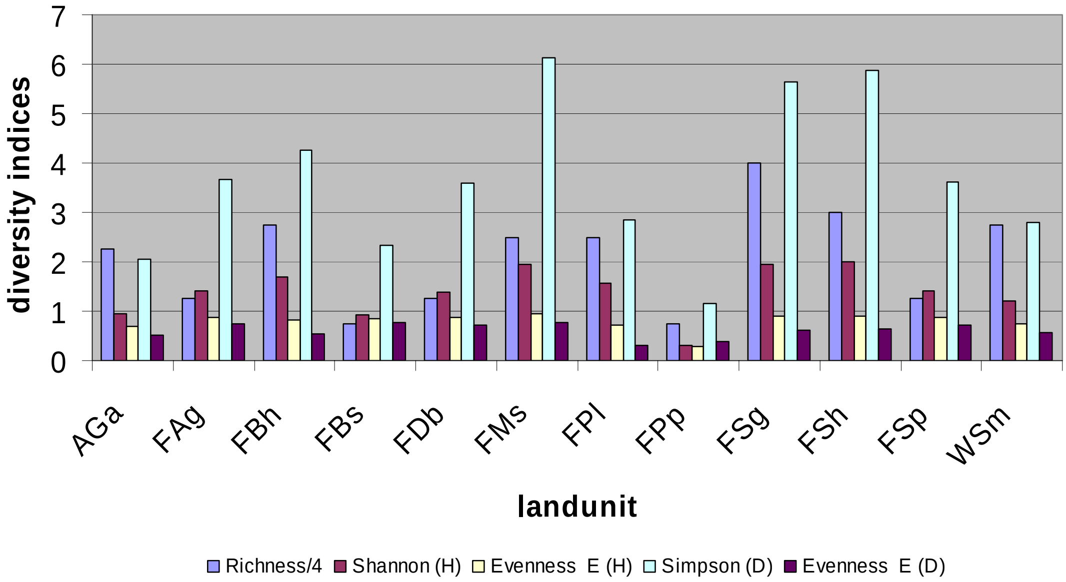

Figure 11: Diversity indices for insects, at genus level (selected units).

Most diverse for *fishes* are the main rivers (WRm), but these are sampled much more then the others too.

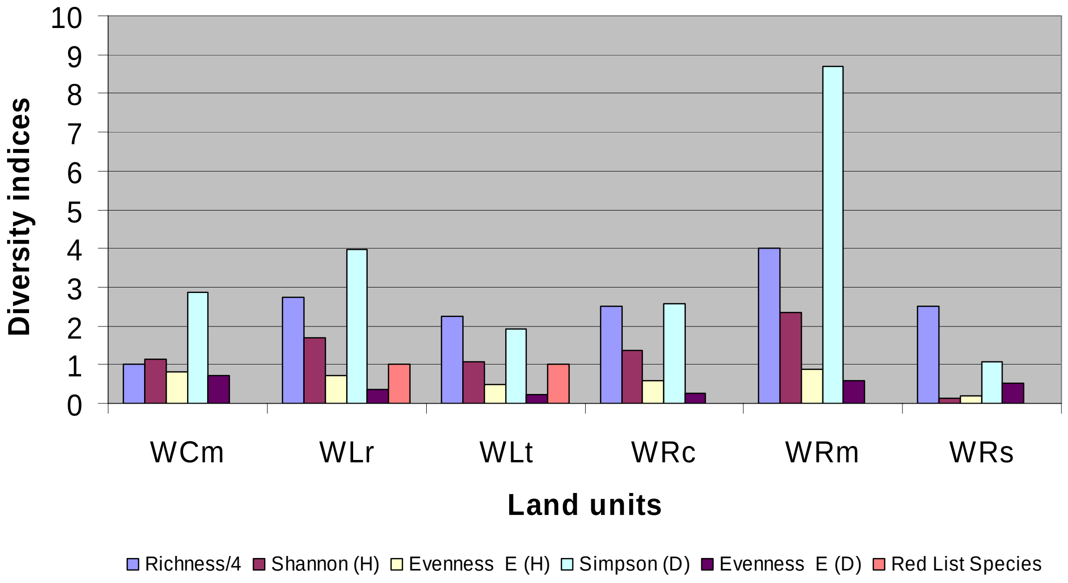

Figure 12: Diversity indices for fishes (selected units).

The *mosses* show low overall diversity values (Appendix 4). Most diverse Land Units are aspen forest (FAg), tall sedge marsh (XFc) and mountain tundra (XMt). *Lichens* on the other hand show very high species richness in Aspen forest (FSg), Mixed forest, birch and pine dominated (FMb, FMp), open mountain forest (XMm), and spruce forest (FSp).

There is a striking difference between those Land Units with high diversity for higher plants and those Land Units with high diversity for lichens (Figure 13). Forest types, in particular pine forest (FPl, FPg, FPs), mixed forest, pine dominated (FMp) and disturbed forest (FDl, FDg, FDs) have low plant richness, but may still be rich in lichen numbers. Antropogenic grassland areas (AGh, AGg) as well as riverine areas (WSs, WSg) may be very rich in plants, and rather poor in lichens.

In particular birch forest (FBh) and natural riverine grassland (WGn) has high values for both, in Red List species as well as diversity values (appendix 2).

Benthos show high species richness in those Land Units that have been sampled most intensely, i.e. main rivers (WRm) and small rivers (WRs), but high species richness is also observed in resp. mountain and tundra lakes (WLm, WLt) and oxbows (WRc) (appendix 2).

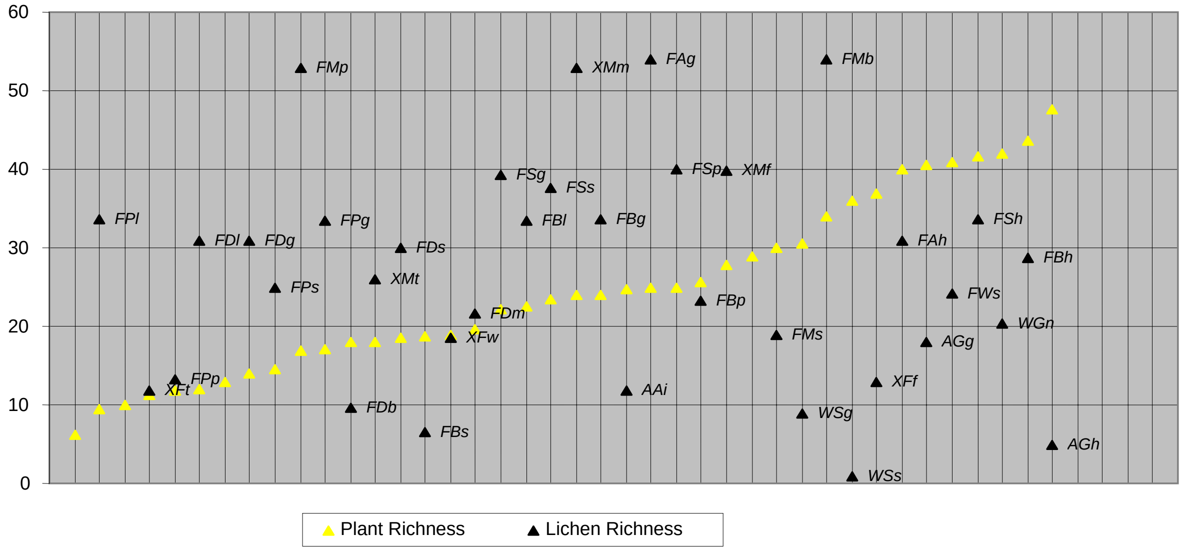

Figure 13: Species richness for vascular plants and lichens

4.5 Rarity of species

Rare species consists of endemic species, Red List species, or protected species. The Red List species and protected species of the Komi Republic are the same, and all endemic species are included in the Red List (Taskaev, 1998), so we discuss here further only the Red List species. There is a discrepancy between Red List of species present (Table 7) and Red List species observed in the Pechora Basin (Table 10). This may be due to the sampling intensity, the coverage of specific ecosystems within the Pechora Basin, the distribution of selected field work areas, and rareness of species. In general only some one-third of the Red List species was encountered during field work.

Table 10:Total number of Red List species observed during field work in 2002 and 2003.

Per site:	Vascular plants	Lichens	Mosses	Birds	Mammals	Fishes	Insects	Herpeto fauna
Red List species	7	24	?	12	-	2	2	

Endemics are very rare, *Anemonastrum biarmiense* and *Gypsophila uralensis* were observed several times in different Land Units during fieldwork in the Ural mountains (Table 11): birch, spruce and willow forest (FBh, FSg, FWs), riverine grassland (WGn), and mountain tundra and fir forest (XMf, XMt).

Table 11: Endemic plant species observed in Pechora (Degteva et al., 2002, Leummens et al., 2002, 2003).

Latin name	Land Unit
Anemonastrum biarmiense Gypsophila uralensis	FBh, FSg, FWs, WGn, XMf, XMt

Detailed information for all land units is found in Appendix 2. The Red List data has been aggregated to a higher level in Table 13 and (Figure 14).
Most *bird* species were observed along the river: 9 Red List species in total (Table 13). In Spruce forest and mixed forest 2 species were observed. Some 6 species are observed along the Main course of the river, WRm. This can be explained partly by the openness of the habitat, which makes it easier to observe birds, the location of field work camps along the river, and the fact that a long transects was laid along the river (by boat, 60 km).
No Red List *mammal* species were observed during field work.
Only one Red List *amphibian* species was observed, *Salamanderella Keyserlingii* larvae were found in road drainage pits (AAd).
Red List *insect* species were found in birch and spruce forest (FB, FS). The number of observations is however very limited, which can be explained by the focus on soil invertebrates.
Red List *Fish* species have been caught in lakes, either along the river or in the tundra (WLr, WLt). It is striking that no Red List species were observed in the main river, nor in the coastal delta.
Important for *vascular plants* are grazed meadows (AGg), aspen forest (FAh), birch forest (FBh) with 6 Red List species, spruce forest (FSh) 2 Red List species, natural riverine grassland (WGn) with 4 Red List species, sandbanks (WSs) and rich fens (XFf).

Table 12: Observed Red List vascular plant species Pechora (Degteva et al., 2002).

Latin name	Status	Plant community
Anemonastrum biarmiense	2 (V)	FBh, FSg, FWs, WGn, XMf, XMt
Dactylorhiza traunsteineri	2 (V)	FSs, FWs, WGn, XFw
Paeonia anomala	2 (V)	Fag, Fah, FBh, FSh, WGn
Pinus sibirica	2 (V)	FS, FP, FB, XM, FM, Fag, FWs
Rhodiola rosea	2 (V)	FBh, FWs, WGNn, WSg
Gypsophila uralensis	2 (V)	WSg
Dryopteris cristata	3 (R)	FBh
Dactylorhiza maculata	supervision required	AGh, FBh, FBs, FPs,FWs,WSg, XFf, XFw

For *lichens* pine forest (FP) with 15 Red List species, willow forest (FWs) 9 species, natural riverine grassland (WGn) with 8, Aspen forest with 12 (FAg), and birch forest (FBh) with 9 Red List species are important Land Units.

Since endemics are scarce, and rarely observed (Table 11), the absolute number of Red List species in a relevée or site is an important indicator for the biodiversity.

Table 13: Number of Red List species per Main Land Unit class; - = no observations (total table in Appendix 2).

	AA	AG	FA	FB	FD	FM	FP	FS	FW	W	WG	XF	XM	Total
Birds	2	1	0	0	0	2	1	2	0	9	-	0	1	12
Mammals	0	0	0	-	0	0	0	0	0	0	-	0	-	0
Herpetofauna	1	0	0	0	0	0	0	0	0	0	0	0	-	1
Insects	0	0	0	1	0	0	0	1	0	0	0	0	0	2
Fish	-	-	-	-	-	-	-	-	-	2	-	-	-	2
Benthos *	-	-	-	-	-	-	-	-	-	0	-	-	-	0
Vascul. plants	1	2	2	6	0	1	2	4	4	3	4	3	2	7
Lichens	0	0	12	9	0	5	2	15	9	0	8	3	9	24

* No Red List exists for Benthos species

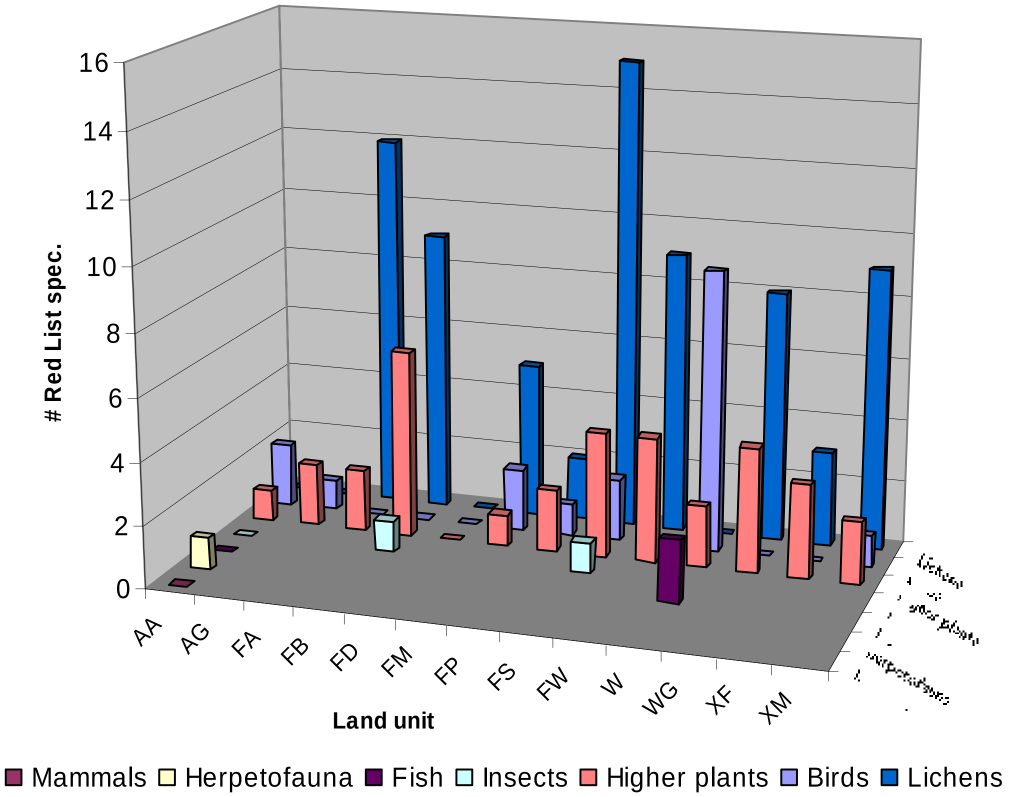

Figure 14: Red List species per (generalised) land unit.

4.6 Dead wood

It is well known from literature that for most species groups' dead wood is very important for the diversity of species. Dead wood can be considered an important indicator especially for lichens, insects, particular bird assemblages, but also vascular plants, mosses and fungi.

The presence of dead wood has not been assessed in all relevés in a similar way. A more detailed statistical analysis of the relationship between important species, presence of dead wood and age of the forest is required to show relationships between dead wood and their occurrence. This analysis was foreseen in this study; however, no analysis was carried out. Ideally the statistical analysis should present the quantitative relationship between quantity of dead wood (standing, lying) and occurrence of particular species.

For the time being literature sources can be used. Jonson & Jonsell (1999) describe the correlations between forest stand indicators and biodiversity, in particular of species diversity, the occurrence Red List species, and indicator species.

At a later stage, more effort should be put to define the statistical relationship between occurrence of Dead wood and biodiversity. Additional field work, with standardized description of dead wood, would facilitate this analyses greatly.

4.7 Conclusions

The data for different genera has been adjusted in some aspects to make them comparable. In particular to quantify densities or number of observations per unit (time, area) were defined.
The use of indicator species lists (of the WCMC) was tested, for butterflies, mammals and birds. In particular the list of butterflies did not seem to be very representative for Pechora River Basin. It may be possible to define more specific indicator species for the Pechora River Basin area, however, this has not been done yet for the entire area, and with the present data and analysis it is not yet possible to do this.
Species richness and species diversity was defined for all groups. The diversity in data and inventory methods does not allow direct comparison of these values. Moreover, for most groups the simplest measure, species richness, seems to be easiest to define and to use. Obviously, highest diversity for different taxa may differ very much for the land units.
Of the rare species, the Red List species may be best indicator for the different groups, based on the number of Red List species present and their coverage in the field survey. Some species groups were much underrepresented though in field work, like mammals, herpetofauna, and insects. This is related to the composition of the list and distribution of the species. For some species groups Red List species are a very useful addition though, like birds, vascular plants or lichens.
Dead wood may be an important indictor for biodiversity, but available data is limiting the use of this parameter.

In general the forest areas are very important for biodiversity: the highest species numbers and Red List species are found in spruce and pine forests. This is the case for birds, mammals, insects, vascular plants and lichens (appendix 4).

Anthropogenic areas (AA) have a high species richness for birds, and in particular along infrastructure (drainage ditches etc) for amphibians.
Also grasslands – in particular natural, riverine grassland (WGn), are important for vascular plants, lichens and insects. Similarly for aspen and birch forest (FA, FB), which are species rich for the same taxa.

Water and shore habitats are by definition very species rich in aquatic groups, fish and benthos, but also in vascular plants. Bird observations for the Pechora Delta has been classified according to MODIS classes, and are therefore not directly linked to the land units, but definitely highest species numbers would be found for the coastal habitats. Fens and bogs, XF, are in particular important for herpetofauna and moss species. The communities are however not species rich, as is shown in Appendix 4.

5 Biodiversity at Pechora river basin level

5.1 Introduction

As indicated in 3.1, biodiversity indicators are used at different scale levels. In Chapter 4 the results for indicators at regional (stand) level were described. In chapter 5 the indicators at river basin level are described, and an attempt was made to extrapolate the data from Chapter 4 to the river basin level.

5.2 Methods and preparations

All relevant field data was linked to Land Units, a hierarchical classification discussed in § 1.4, 4.2 and Appendix 1.
A conversion table was prepared from Land Unit to MODIS classes (Table 14). Modis stands for Moderate-resolution Imaging Spectroradiometer, and is measuring comprehensively the state of Earth's environment and ongoing changes in its climate system (Den Hollander & Van Eerden, 2004). MODIS has 250m resolutions in 2 bands.

Table 14: Conversion table from Land Unit to MODIS class.

MODIS class	Vegetation type	Land Unit
1	Coastal meadows	WSt, WSm, WSr
2	Northern tundra, dwarf shrubs & lichen	XNl
3	Northern tundra, dwarf shrubs & moss	XNh
4	Boggy tundra	Xso, XSw
5	Northern tundra, wet	XNc
6	Southern shrub tundra	XSc, XSf
7	Rich fen, Carex	XFf, XFc
8	Meadows/willow shrub	FWs, FMw, WGn, Agg, Agh, Aga
9	Mountain tundra	XMt
10	Poor fen, raised bog	XFt, XFs
11	Poor fen, partly wooded with pine	XFw
12	Spruce/dark coniferous forest (> 70%)	FSg, FSp, FSs, FSh, XMf
13	Mixed forest, spruce dominated	FMs
14	Pine forest (> 70%)	FPg, FPl, FPp, FPs
15	Mixed forest, pine dominated	FMp
16	Unclassified pine/bush fire	FDb
17	Disturbed forest, clearcut/regrowth	FDg, FDl, FDm, FDs
18	Mixed forest, birch dominated	FBg, FBl, FBp, FBs, FBh, FMb
19	Mixed forest, aspen dominated	Fma
20	Mountains, Open forest	XMm
21	Mountain, bare rock	XMb
22	Sandbank, bare soil, dunes	WSs, WSg, WSd
23	Water	WRm, WRs, WRc, WRd, WLr, WLm, WLt, WLp, WCm, WCl, WCt, WCf
24	Mountain, snow	XMg
25	Urban area	Aau, Aar, Aad, Aai

5.3 Naturalness

The Ministerial Conference on the Protection of Forests in Europe (www.mcpfe.org) considers naturalness as important (§ 2.5.1), but also the general approach of biodiversity attaches a high value to naturalness (Table 1). The concept was however developed in Western Europe, and may therefore be of less relevance for the Komi Republic and Nenets autonomous district.

The naturalness can either be defined on the basis of the relevée descriptions, or based on general forest management and infrastructure maps.
Based on the pristine forest map (e.g. from the local NGO Silver Taiga or Taiga rescue network (http://www.forest.ru/eng/publications/last/maps/komi.html) we know where the natural, pristine forests are. In most of the territory valuable timber species have been exploited, in particular pine trees have been cut, so most forest can not be considered natural anymore. In the early forestry periods selective cutting took place, with relative little impact, during past decades more large scale clearcut practice was common. Forest plantations are not common at all, so most forests can nowadays be considered semi-natural. The urban areas are the other extreme, unnatural.
These maps could be combined to come to the naturalness map:

Table 15: Maps indicative for naturalness of habitat.

Class	Map
Undisturbed	map Silver Taiga, Taiga Rescue network etc. http://www.forest.ru/eng/publications/last/maps/komi.html
Semi-natural	all forests which are not undisturbed or planted
Plantations/not natural	urban area plantations (map?)

The required maps are unfortunately not available yet in the Pechora GIS. The core map, with undisturbed forest areas is presented below (Figure 15), which is in digital format available.

Based on field data an analysis was done of the correlation between naturalness and biodiversity. From 185 forest samples, 91 contained information on disturbance, which varies from natural, undisturbed forest to selective cutting and tracks of fire (Appendix 5). The samples were divided into 4 classes of naturalness based on information on management regime and disturbance. Class 1 means undisturbed natural forest; class 4 means much disturbed, for example where selective cutting is going on (Appendix 5).
The statistical analysis shows that little correlation exists between naturalness, and the different diversity indices for all plants in the same plot (see also Table 16 and §6.2).

Table 16: Correlation (r) between diversity indices and the degree of naturalness.

Correlation coefficient (r) (Ind:Naturalness)	Richness	Shannon index	Evenness	Simpson	evenness
all plants	-0.32	-0.32	-0.23	-0.15	-

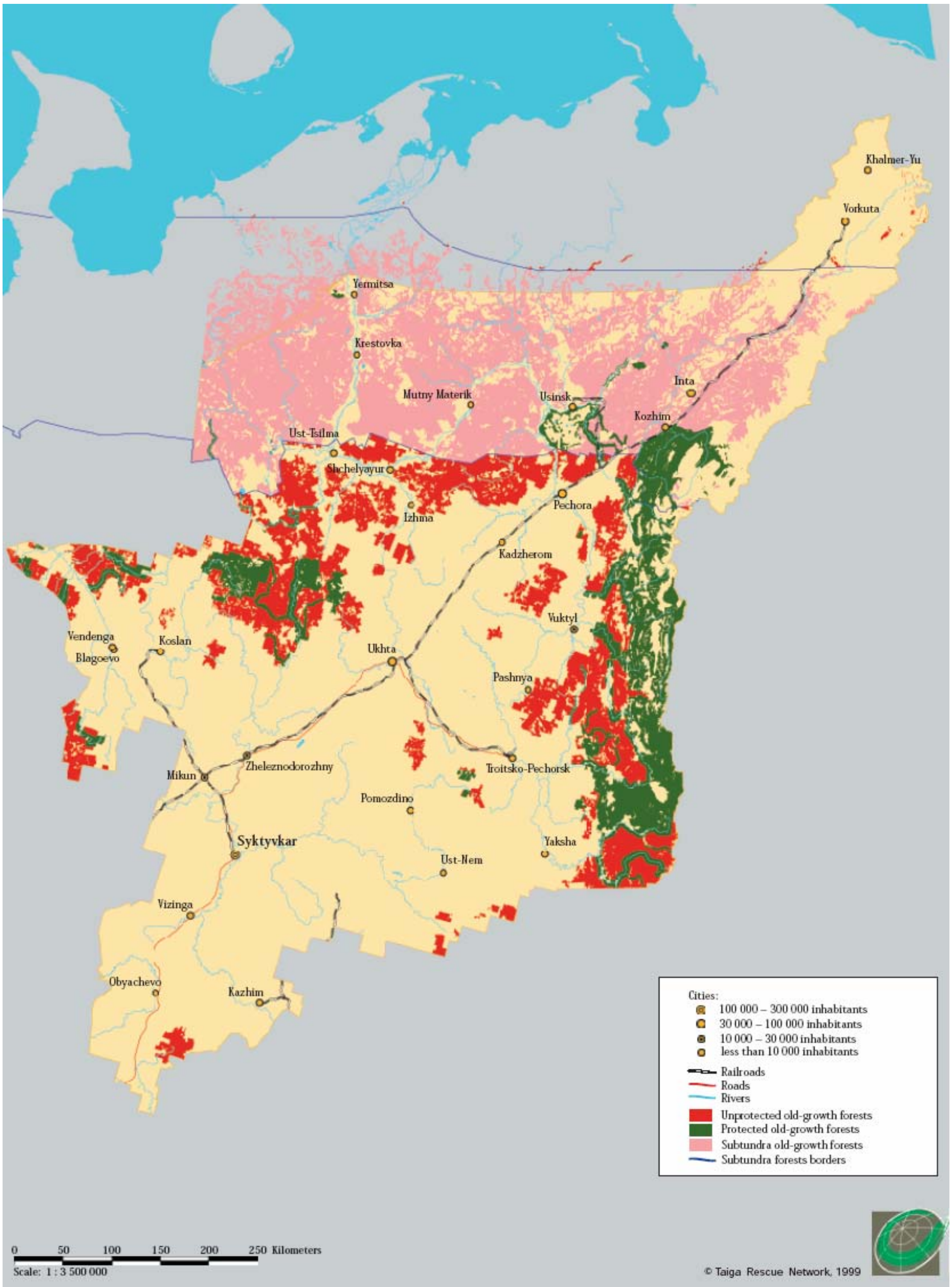

Figure 15: Old-growth forests in the Komi Republic (Taiga rescue network, 1999)

5.4 Minimum area size/Landscape pattern

Landscape pattern may be defined in different classes of fragmentation. Leading should be the habitat requirement for some species. As an example for this approach, a fragmentation map is presented here derived from satellite imagery (Figure 16), based on Ritters *et al.* (2000). It shows that, despite the large scale of forests, there is some interior fragmentation.
Despite this, it is likely that fragmentation is not yet an issue, considering the large populations of species with large habitat requirements like the brown bear or wolf. Still, as discussed in § 3.2, it is a parameter which is of importance for boreal forests.

A more detailed analysis is recommended for each taxon, in particular for umbrella or keystone species (Noss & Cooperrider, 1994) e.g. for large carnivore species, medium sized mammal species (Brown bear, Elk), and a medium size forest bird (Capercaillie, *Tetrao urogallus*) and possibly a lichen species. Based on the home range and habitat requirements, habitat should be classified according its potential suitability:
1 = totally fragmented, not suitable
2 = fragmented but local populations possible
3 = reasonable well connected, viable key populations
4 = well connected extensive habitat

However, as long as no distribution maps are available for relevant species, as well as more detailed habitat/vegetation maps, it is not possible to assess further the rate of fragmentation for any of these species.

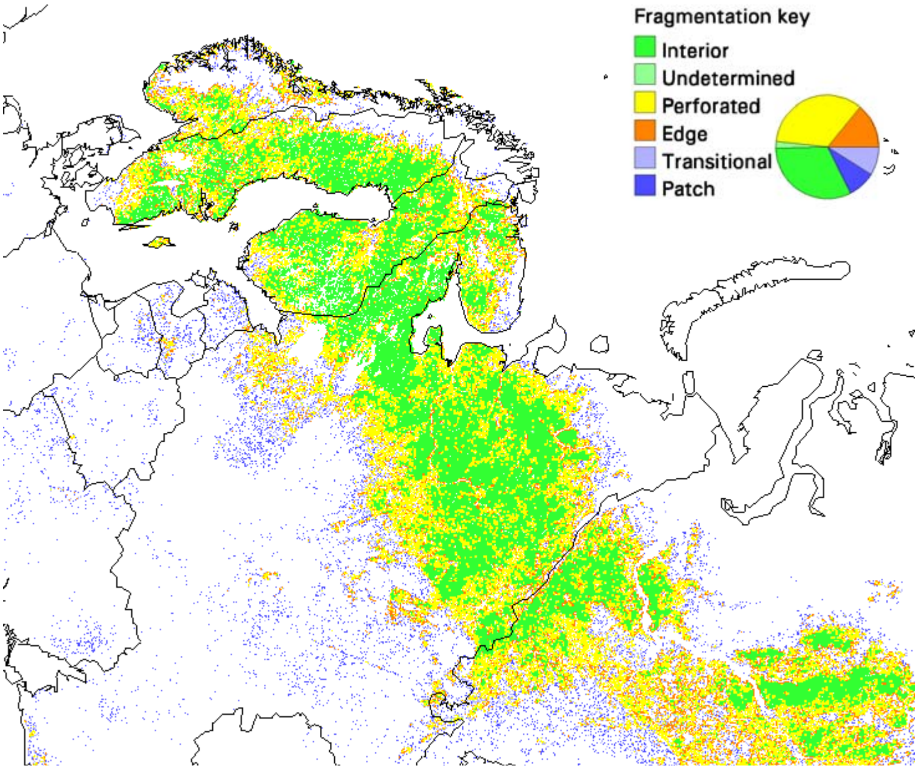

Figure 16: Fragmentation of boreal forest in Europe and Asia (Ritter et al., 2000)

5.5 Ecosystem rarity

Ecosystem rarity (ER) is defined on the basis of the share of the specific ecosystem type in total land cover. The share of the ecosystem type is derived from the MODIS classification of the remote sensing image, which covers the entire study area (Version 3 of the classified map, Den Hollander & Van Eerden, 2004).

The rareness value is calculated as follows:

$$ER = \frac{1}{\frac{Area_{LU}^{\;2}}{\sum Area}}$$

in which Area $_{LU}$ = the total area of a specific ecosystem type
and $\sum$ Area = sum area

Some specific types of habitat are rare, the mixed forest of Pine type, and Northern wet tundra.
The MODIS classification may have a bias towards units with a very specific signature, as well as ecosystems which are more extensive in areal distribution. The very rare habitats may therefore not be represented in this table, which makes this parameter less useful.

Table 17: Share of different Vegetation types in the entire Pechora Basin (based on MODIS classification) and the calculated Ecosystem Rarity ER

MODIS class	Area (km2)	Area cover (%)	Vegetation type	ER
1	111054	9	Pine forest (> 70%)	0.0000
2	121295	9	Spruce/dark coniferous forest (> 70%)	0.0000
3	22937	2	Meadows/willow shrub	0.0006
4	1170	0	Mixed forest, pine dominated	0.2353
5	313392	24	Mixed forest, spruce dominated	0.0000
6	74915	6	Mixed forest, birch dominated	0.0001
7	112097	9	Disturbed forest, clearcut/regrowth	0.0000
8	24229	2	Unclassified pine/bush fire	0.0005
9	21497	2	Mountain bare rocks	0.0007
10	2958	0	Mountain tundra	0.0368
11	18699	1	Mountains, Open forest	0.0009
12	5226	0	Northern tundra, dwarf shrubs & lichen	0.0118
13	169663	13	Northern tundra, dwarf shrubs & moss	0.0000
14	235	0	Northern tundra, wet	5.8569
15	29462	2	Boggy tundra	0.0004
16	153907	12	Southern shrub tundra	0.0000
17	10973	1	Rich fen, Carex	0.0027
18	9137	1	Poor fen, raised bog	0.0039
19	36581	3	Poor fen, partly wooded with pine	0.0002
20	13025	1	Sandbank, bare soil, dunes	0.0019
21	24241	2	Water	0.0005
22	11601	1	Coastal meadows	0.0024
SUM:	111054			

5.6 Extrapolation based on MODIS Land Cover map

Based on the MODIS land cover map of the entire Pechora River Basin (Den Hollander & Van Eerden, 2004) the results of the biodiversity assessment can be extrapolated to the entire area. As long as observations are available for different units it is possible to assume that this is predictive for a larger region. However, due to the fact that the area is extremely large, and the limited possibilities for field work in the framework of the PRISM project (4 sub-areas sampled), this does not hold.

The following map (Figure 17) shows the pixels for which no data is available in the database developed in the PRISM project. In particular the tundra areas in the far north, as well as mountainous regions of the Ural Mountains, were less well covered, only bird data was available. Still the results of extrapolation may be seen as an approach for presentation purposes, they are however only indicative, and by no means conclusive for biodiversity.

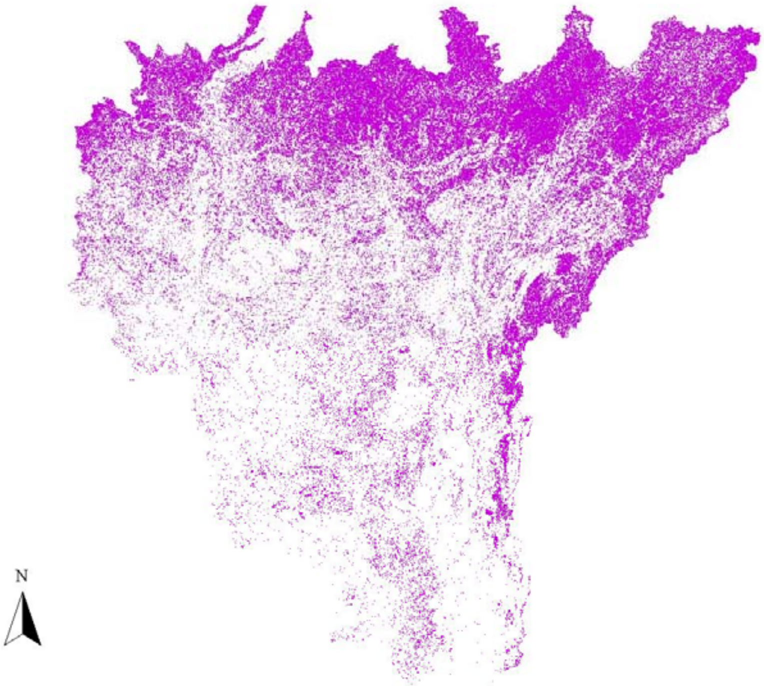

Figure 17: Pixels of the MODIS image for which no diversity data is available.

5.7 Generalisation results to basin level

If we convert the different Land Units to the MODIS classes (Table 14), the data of different land units are combined in a new class. In this way, average species numbers (Table 18) and the sum of Red List species (Table 19) have been defined for the MODIS classes. It may be obvious that we loose detail.
The results of some species groups like fish or benthos seems less relevant at river basin level, since no habitat differentiation exists in the MODIS maps.

Table 18 and Figure 18 show average species number for *birds*. They are numerous in the tundra and coastal areas, in particular coastal meadows (84 species) and Northern tundra (75) rank very high. However, these data were compiled directly for MODIS classes, whereas the other bird data was attributed to land units and then to MODIS class, and are therefore data are not entirely comparable (see e.g. the difference for Meadows/willow shrub, with 19.75 species resp. 47 species).
Birds species are in particular numerous in spruce/dark coniferous and pine forest, as well as mixed forest dominated by spruce and pine. This forest type is likely to be most abundant in pristine forests, which are rarely formed by mono-specific stands.
Red List bird species are numerous along the water, and also for spruce/dark coniferous forests (Table 19, Figure 19).

Table 18: Number of species per MODIS class (figures in italic are derived from compilation of figures of previous years, and not comparable with other figures; marked are above average values).

Modis	Birds	Mam-mals	Insects (spec)	Insects (genus)	Fish	Ben-thos	Vasc. plants	Mosses	Lichens
Pine forest (> 70%)	39.00	6	11.25	7.00	0	0	13.23	4.91	26.33
Spruce/dark coniferous forest (> 70%)	41.75	6	31.40	9.40	0	0	27.99	7.71	38.10
Meadows/willow shrub	19.75/*47*	6	25.00	8.60	0	0	42.75	2.56	16.91
Mixed forest, pine dominated	53.00		7.00	6.00	0	0	17.00	6	53
Mixed forest, spruce dominated	56.00		14.00	10.00	0	0	30.00	8	19
Mixed forest, birch dominated	19.57		18.14	6.43	0	0	29.20	6.62	33.07
Disturbed forest, clearcut/regrowth	12.75		10.25	3.75	0	0	16.07	8.13	28.42
Unclassified pine/bush fire	18.00	4	3.00	5.00	0	0	18.00	4.67	9.67
Mountain bare rocks	-		-	-	-	-	-	?	?
Mountain tundra	16.00		2.00	2.00	0	0	18.00	5.5	26
Mountains, Open forest	12.00		0.00	0.00	0	0	24.00	4	53
Northern tundra, dwarf shrubs & lichen	51		-	-	-	-	-	-	-
Northern tundra, dwarf shrubs & moss	75		-	-	-	-	-	-	-
Northern tundra, wet	43		-	-	-	-	-	-	-
Boggy tundra	68		-	-	-	-	-	-	-
Southern shrub tundra	-		-	-	-	-	-	-	-
Rich fen, Carex	54		0.00	0.00	0	0	25.00	8.50	13
Poor fen, raised bog	18.00	3	2.00	1.00	0	0	10.63	5.04	11.8
Poor fen, partly wooded with pine	8.00	2	13.00	4.00	0	0	18.92	8.40	18.5
Sandbank, bare soil, dunes	13.50/*32*		8.00	3.00	0	0	33.29	2.25	5
Water	29.20	6	0.00	0.00	10	18.22	6.25	1	0
Coastal meadows	84		28.00	11.00	0	0	0.00	0	0
no modis	30.67		5.33	3.33	0	0	26.88	2.83	11.8

Vascular plant diversity is high in particular in meadows (with some willow shrub), on sandbanks and bare soils (often related to the river) and mixed forest dominated by spruce (Table 18). These results differ therefore from the more detailed assessment per Land Unit, where in particular forests have high biodiversity values.
These areas stand out in particular along the Pechora River (Figure 20).
The Red List data shows that for vascular plants (and lichens) also meadows with open willow vegetation and mixed forest dominated by birch is important, for plants also poor fens, and sandbanks (Table 19, Figure 21)

Figure 22 and Table 18 show *lichen* diversity. Diversity is in particular high in mountain forests (usually pristine forests on the slope of the Ural Mountains) but also in spruce forest, and mixed forests dominated by pine and birch (note however that some of these observations are based on a very small number of samples!).
Most Red List species are found in Spruce/dark coniferous forest, as well as meadows with willow shrub (Table 19, Figure 23).

Mammal diversity is high in the northern part, the tundra area (Figure 24), based on 'meadows and willow shrub', as well as in pine and spruce forests and riverine territories.

Figure 25 shows the *insect* diversity. Insects are abundant in spruce forest, but striking is also their abundance in meadows. This may be related to soil and humus conditions, and contribution of species like butterflies, bumblebees, dragonflies etc. These units are apparent in the Southern Ural mountains and floodplains along the Pechora River.

It is not considered useful to prepare maps for *fish* and *benthos* species, since only one type of water is classified in the MODIS images. The more detailed analysis in paragraph 4.4 and 4.5 is therefore more appropriate.

Finally, a map has been prepared on the basis of the presence of all Red List species (Figure 26). Highes diversity is found in the mountainous region in the south, as well as along the rivers. Obviously, the map has many similarities with the lichen Red List map, which has the largest share of Red List species.

Table 19: Number of Red List species per MODIS class.

Modis	Birds	Insects (spec)	Fish	Plants	Lichens
Pine forest (> 70%)	1	0	0	1.33	1.33
Spruce/dark coniferous forest (> 70%)	5	1	0	2	9.25
Meadows/willow shrub	4	0	0	2.5	8.5
Mixed forest, pine dominated		0	0	1	4
Mixed forest, spruce dominated	2	0	0	1	1
Mixed forest, birch dominated		1	0	2.5	6.25
Disturbed forest, clearcut/regrowth		0	0	0	0
Unclassified pine/bush fire		0	0	0	0
Mountain bare rocks					
Mountain tundra	1	0	0	2	1
Mountains, Open forest		0	0	1	4
Northern tundra, dwarf shrubs & lichen	6				
Northern tundra, dwarf shrubs & moss	6				
Northern tundra, wet	2				
Boggy tundra	7				
Southern shrub tundra					
Rich fen, Carex	7	0	0	1	0
Poor fen, raised bog		0	0	1	0
Poor fen, partly wooded with pine		0	0	3	3
Sandbank, bare soil, dunes	3	0	0	2	0
Water	9	0	2	0	0
Coastal meadows	8	0	0	0	0
no modis	2	0	0	1	0

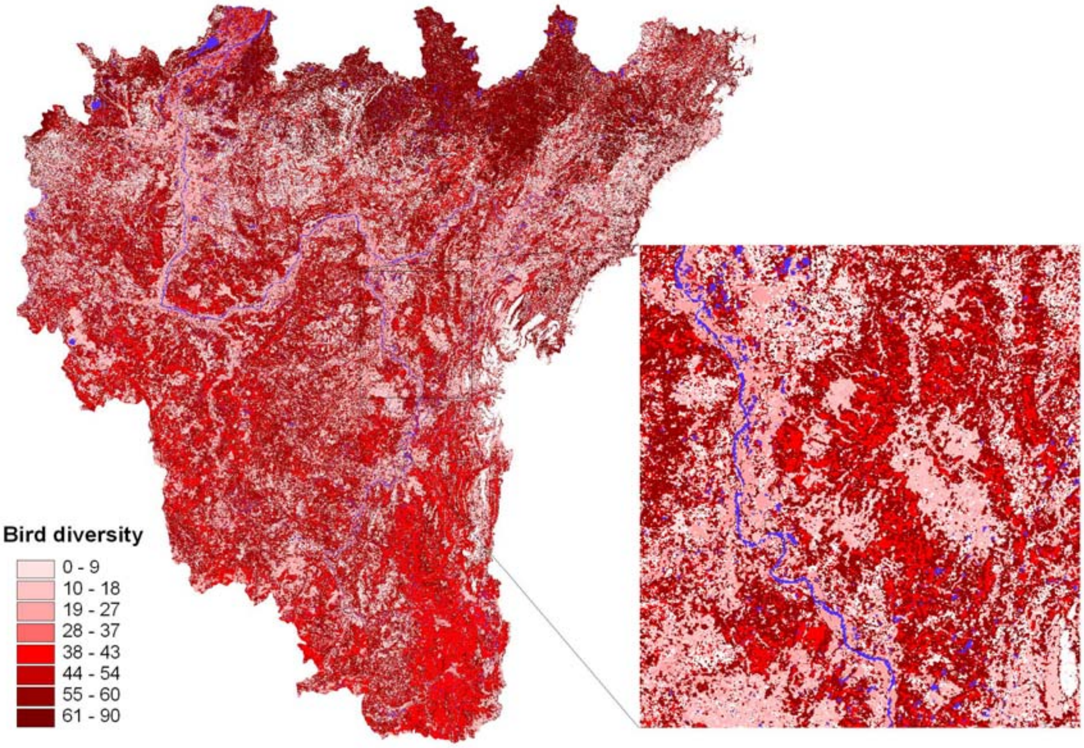

Figure 18: Bird diversity, based on average species number per MODIS class.

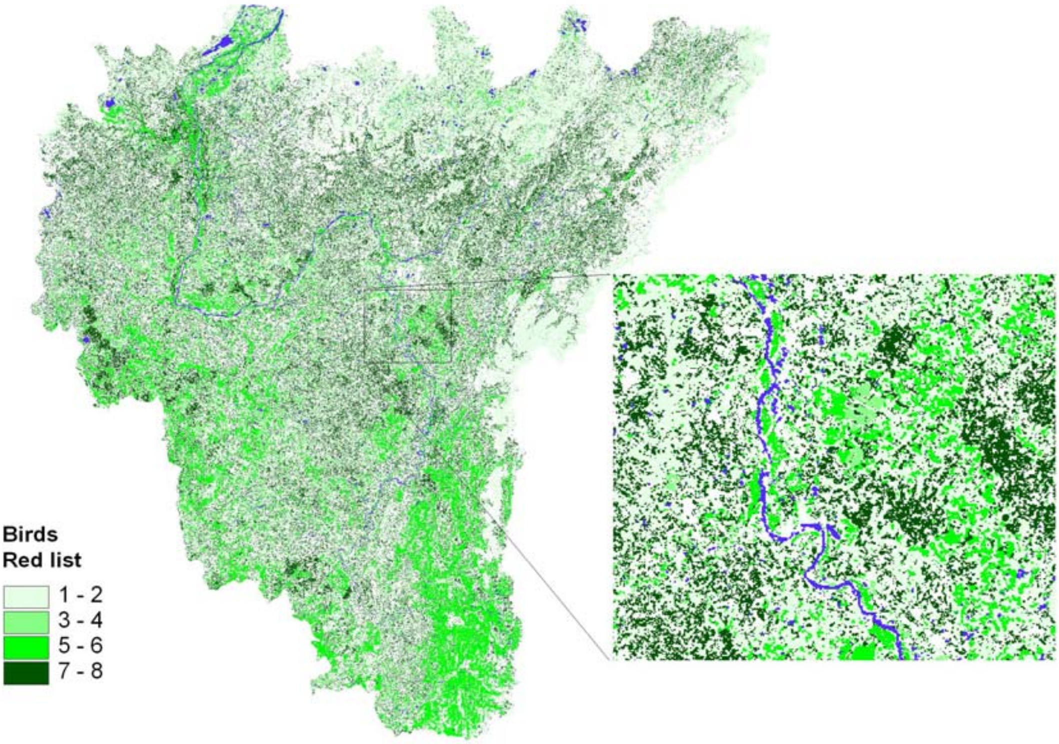

Figure 19: Red List species for birds, summarised per MODIS class.

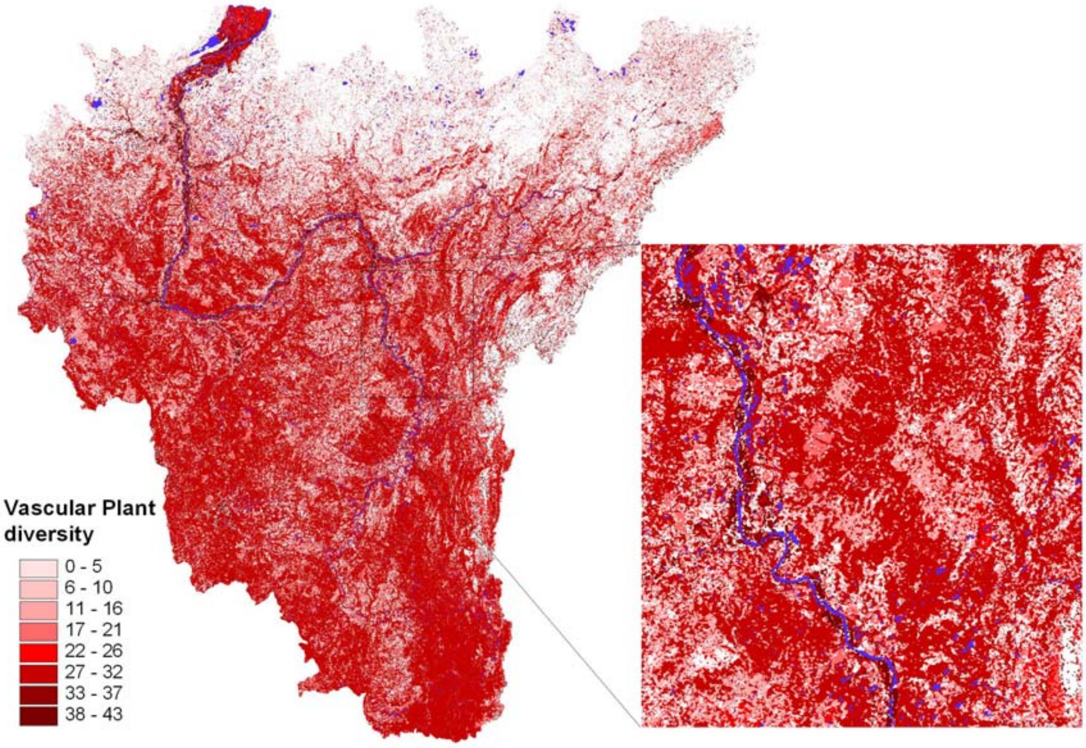

Figure 20: Vascular plant diversity, based on average species number per MODIS class.

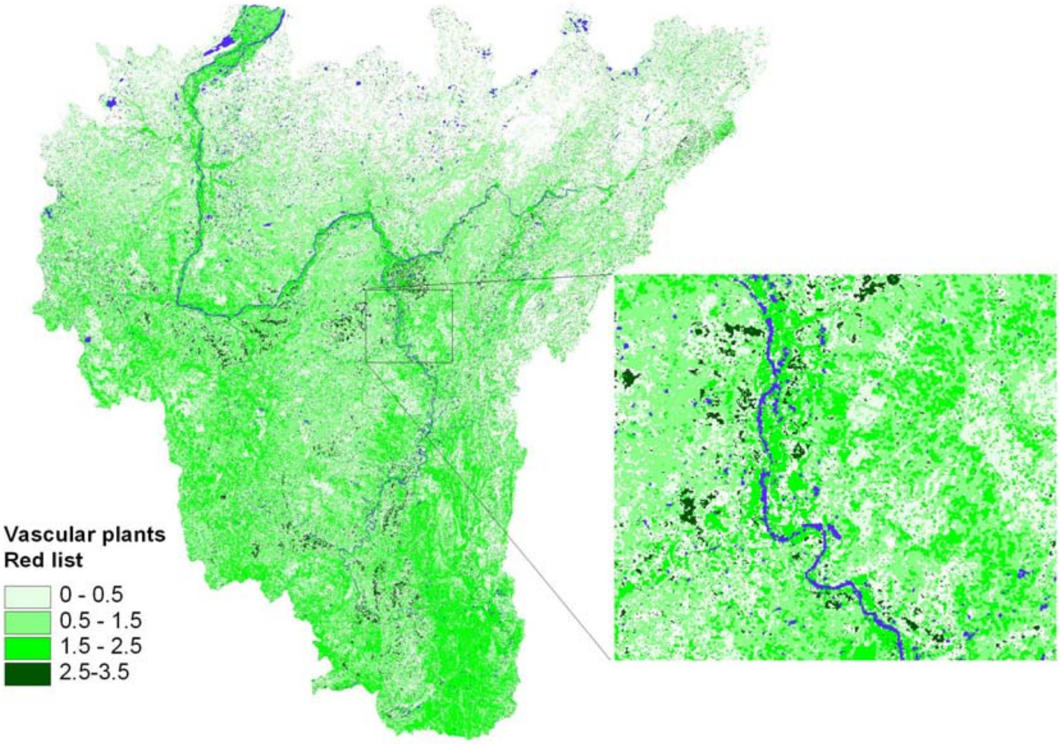

Figure 21: Red List species for vascular plants, summarised per MODIS class.

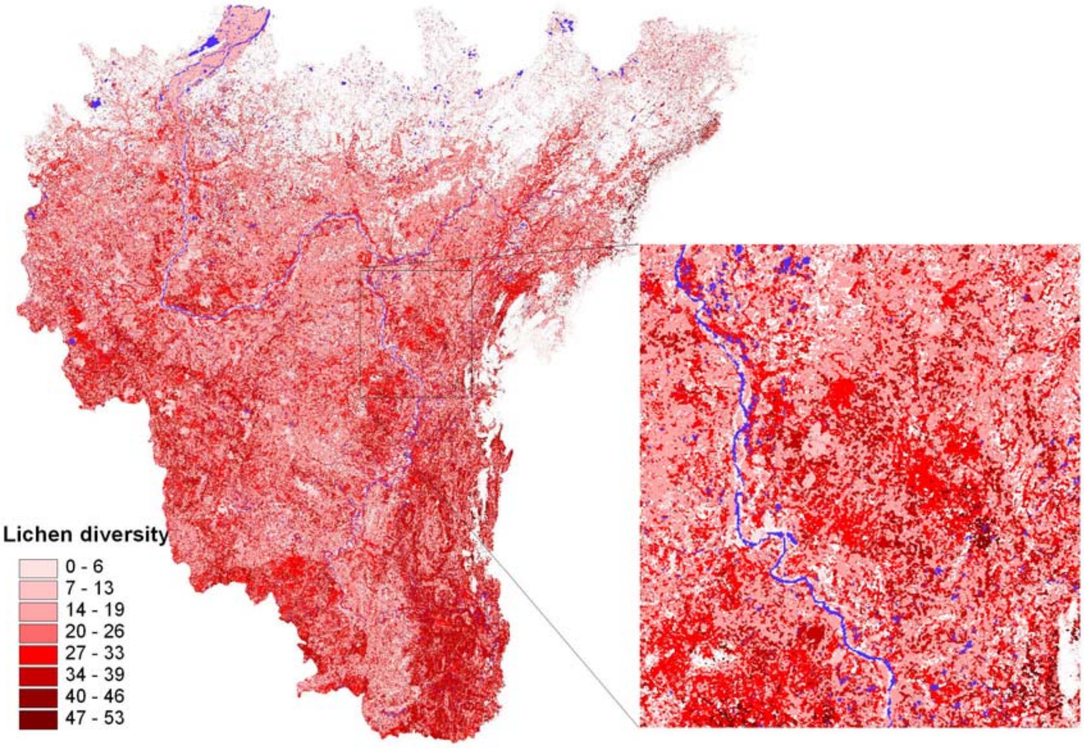

Figure 22: Lichen diversity, based on average species number per MODIS class.

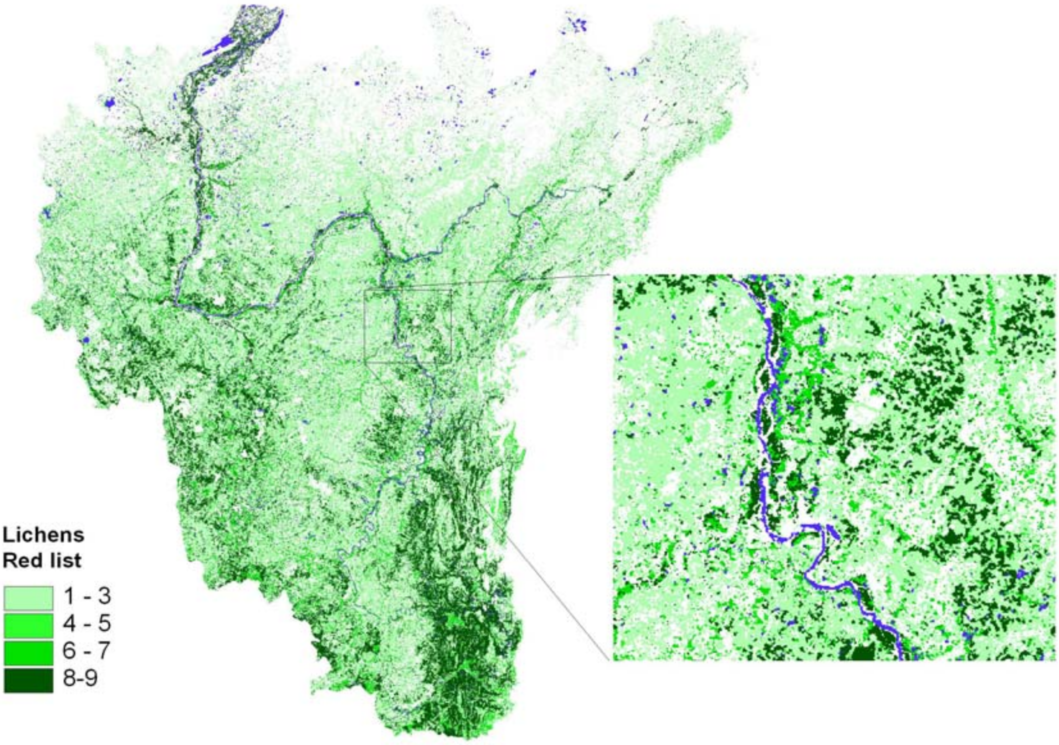

Figure 23: Red List species for lichens, summarised per MODIS class.

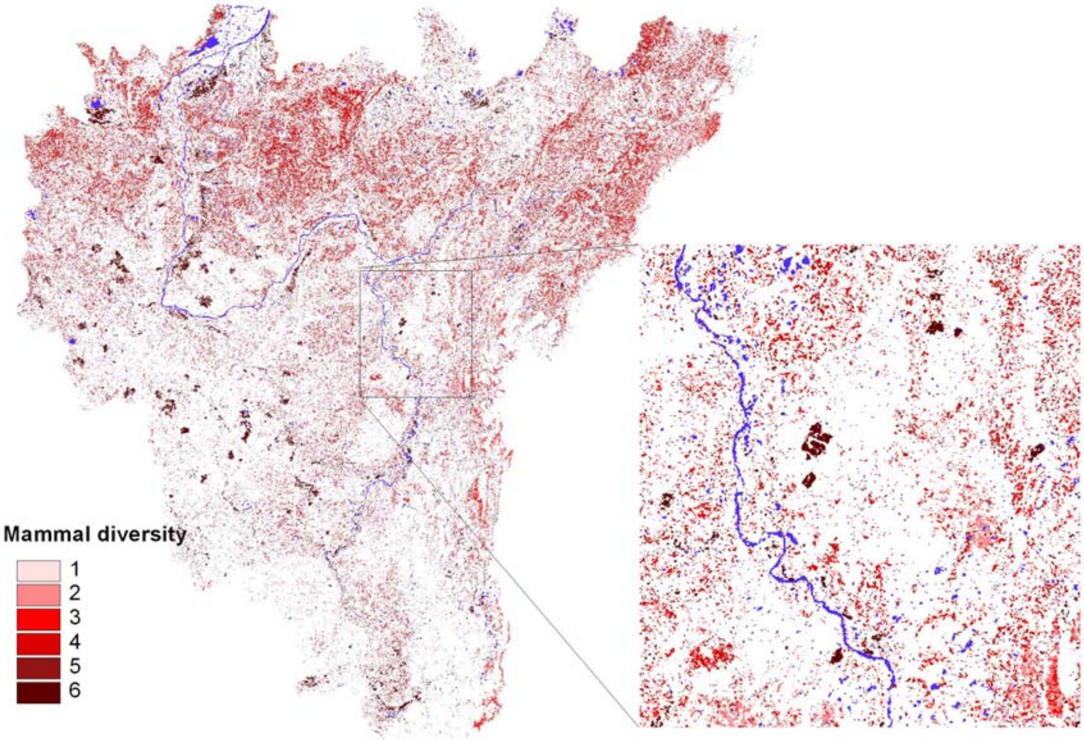

Figure 24: Mammal diversity, based on average species no. per MODIS class.

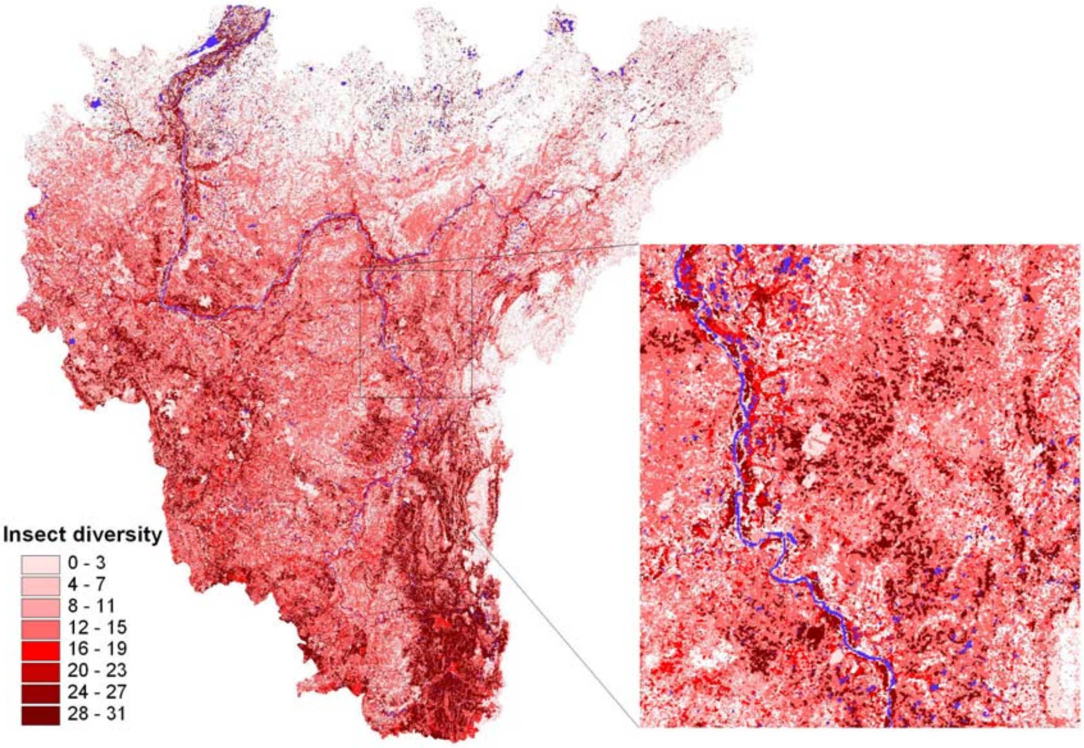

Figure 25: Insect diversity, based on species number per MODIS class.

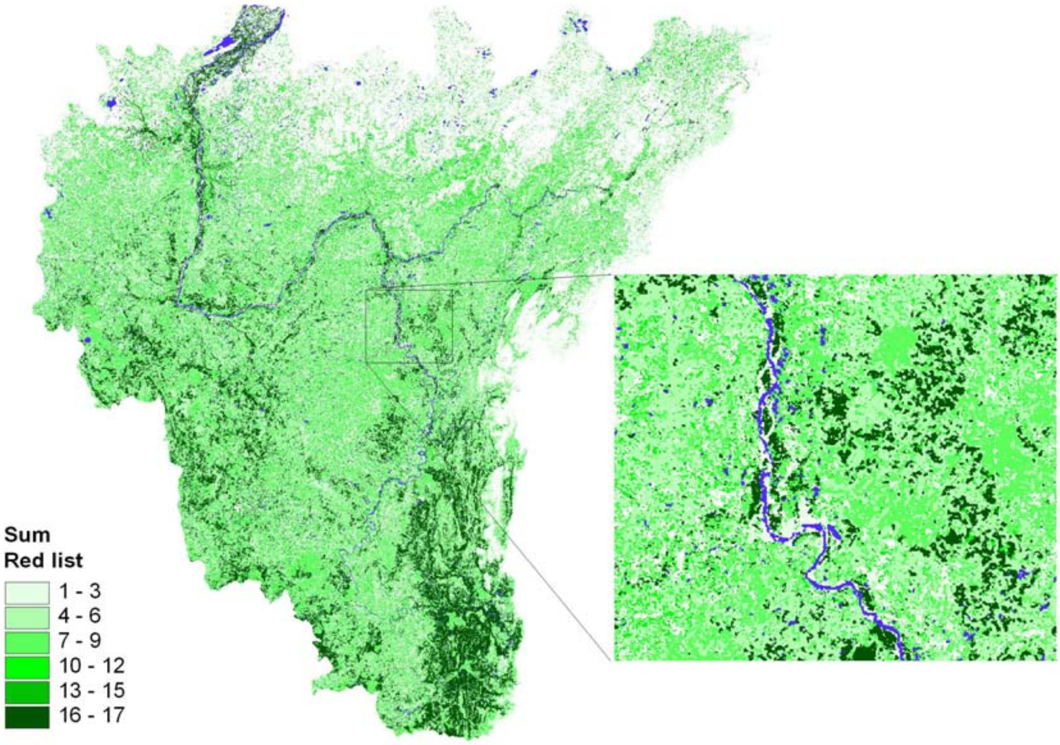

Figure 26: Red List species (birds, plants, lichens, insects, fish) summarised for MODIS classes.

5.8 Conclusions Biodiversity at River Basin level

In general the forest areas are very important for biodiversity: high species numbers and high numbers of Red List species for birds, mammals, insects, vascular plants, mosses and lichens are found in spruce and pine forests, mixed spruce, pine and birch forest as well as meadows.

The Northern tundra and boggy tundra has high bird species richness, and counts also many Red List species for birds. For other species groups data is lacking in the dataset used here.

Rich fen and poor fen are important for moss species mainly, and also here (as compared to § 4.7) may be shown that they are rather species poor, compared to other ecosystems. The highest number of Red List species for vascular plants (3) is observed in these types of habitat.

Open water, which includes rivers and lakes, are rich in benthos and fish species – which is obvious since Modis includes all possible habitats in this one land cover type. The number of Red List species is in particular high for birds (9 species). Also the number of mammals is high, 6, of which 2 are aquatic species (Beaver *Castor fiber*, Otter *Lutra lutra*) and 4 terrestrial species are observed in riverine territory.

Sandbanks (coastal, as well as riverbanks) are important habitat for bird species and vascular plants.

Finally, coastal meadows have absolutely the highest bird species richness, and a high number of Red List species (8).

Looking at the overall study area, and Red List species (Figure 26), we see concentrations of in the Southeastern part, i.e. the Zapovednik area, as a biodiversity hotspot, as well as riverine territories, along the Pechora River. This is mainly defined by the large list of Red List lichen species, and by the fact that for tundra areas only bird data was available.

6 Discussion

6.1 Method for data collection

Not all Land Units have been studied equally well (Appendix 4 and 6: sampling intensity). This may result in high species richness in those units that have been sampled intensively and perhaps low richness for those units that have been assessed only once. Here diversity indices may give additional information, which is not obtained from species richness only.
Also some species groups were not so well sampled, in particular moss species, and herpetofauna. No bryologist was represented in the field team, and samples were therefore taken by the botanist and lichen specialist. For herpetofauna the sampling period was not optimal (too late for the reproduction period) and there were time limitations.

This analysis has been based on field work for two years (for the Southern Pechora Basin), five years for the Pechora Delta region (Van Eerden, 2000). However, considering the size of the territory this field work is very limited, and it is crucial that more data is collected of in particular areas in the western part of the Komi republic, and the far Northeast.

Due to the set-up of the research emphasis was put on investigating forests in the breeding period of birds and flowering season of plants. Existing data for the Pechora Delta based on a five years study (Van Eerden, 2000) was used to add to the database developed in this project. This caused some inconsistencies in approach and data. The most striking difference, however, was caused by the fundamentally different landscape types present. The open areas in the north made it possible to count large areas. The forest work is restricted to transect and point relevée work only. Only transects by boat (bird counts) were on the level comparable to the scale used for assessment in the tundra regions.

The aspect of management was not sufficiently assessed. Age of forests, and management intensity should be better analysed. Even with the present data this may be improved, with existing forest maps.

6.2 Suitability of diversity indices

We calculated different diversity indices; each has its strengths and weaknesses. Species richness is the most obvious one in telling us how many species have been found in a certain area. However, Shannon-Weaver and Simpson diversity indices and evenness can give additional information on the diversity in a community and especially on its numerical structure, but the data is in general too different in character to make comparisons between species groups. For some species groups (e.g. mammals, fish, birds) it is difficult to define diversity indicators. This is due to the above mentioned problem that densities are hard to define, e.g. where transects were laid out, and the observations were averaged per distance unit to come to a measure of 'abundance'. Although it is possible to define also the width of the transect, this differs per species (observation distance) and wasn't done for that reason. To define density or 'abundance' for bird species is obviously very different from a relevé with 40 plant species, each with a specific abundance.

For benthos diversity (Appendix 4), the highest richness (31 families) is found in Land Unit WRm (main rivers) where 129 samples have been taken. Land Unit WLm (mountain lakes) on the other hand has been sampled 13 times and has a species richness of 18, so much lower than in WRm (main rivers), but a Shannon-Weaver diversity index of 2.3 compared to 2.0 and a simpson index of 7.8 compared to 4.3.

An interesting comparison can be made between WLm (mountain lakes) and WLt (tundra lakes) (Table 20). Both have been sampled 13 times and both have a species richness of 18. However both diversity indices show higher values for the mountain lakes then for the tundra lakes. This may be due to the fact that the range of values is a bit larger for WLt in particular the average and minimum value, which results in lower indices. So the indices add something to species richness in general, but the differences may be relatively small.

Table 20: Comparison species diversity for benthos.

Benthos	WLm (mountain lakes)	WLt (tundra lakes)
# Samples	13	13
Richness	18	18
Shannon-Weaver (H)	2,31	1,99
Evenness E (H)	0,80	0,69
Simpson (D)	7,89	5,82
Evenness E (D)	0,44	0,32
Average	1036	891.1
Minimum	11.1	3
Maximum	4268	4120

As for *birds*, the different Land Units have not been sampled very intensively. (Appendix 4). However species richness seems to be high, as well as the diversity indices. It is interesting to have a closer look at Land Units FPg (pine forest, green moss type), FPl (pine forest, lichen type), FSg (spruce forest, green moss type) and WRm (main rivers) (Table 21).

The evenness based on the Shannon diversity index is extremely high, meaning that an even distribution of species exists. From this may be concluded that the Shannon and Simpson indices give more information than species richness alone. The exact meaning of the indices however, is more difficult to grasp. A number of correlation analyses were done to better understand which factors affect the indices the most.

Table 21: Comparison species diversity for birds.

Birds	FPg (pine, green moss)	FPl (pine, lichen)	FSg (spruce, green moss	WRm (main rivers)	FSh (Spruce, herb type
# Samples	6	11	19	12	14
Richness	38	47	75	101	56
Shannon (H)	1,88	1,75	1,84	2,49	1,73
Evenness E (H)	0,95	0,94	0,88	0,83	0,85
Simpson (D)	6,31	6,31	6,67	11,46	4,94
Evenness E (D)	0,81	0,82	0,77	0,51	0,64
Red List species	-	-	2	6	1

First of all we looked at the correlation coefficient between the diversity indices and the total number of species (Table 22). The value of 1 or -1 shows a perfect correlation (resp. inverse correlation), 0 is totally uncorrelated. It shows that both Shannon's and Simpson's index are strongly correlated with the species richness. This is true for all the species groups included in this research, except for the birds. For birds, the correlation between richness and the Shannon and Simpson index is respectively 0.63 and 0.69, due to the equal distribution of birds in each sample. The evenness values are high whereas the richness is not necessarily. The Shannon diversity index seems to be slightly more influenced by species richness than Simpson' index.

Table 22: Correlation (r) between diversity indices and species richness.

Correlation coefficient (r) (Ind:Richness)	Richness	Shannon index	Evenness	Simpson index	evenness
Birds	1	0.63	0.52	0.69	0.46
Insect species	1	0.82	0.53	0.94	0.34
Insect Genus	1	0.82	0.68	0.79	0.50
Fish	1	0.92	0.89	0.90	0.84
Benthos family	1	0.94	0.89	0.88	0.71
Vascular plants	1	0.95	0.85	0.87	-
Mosses	1	0.84	0.45	0.73	-
Lichens	1	0.92	0.77	0.82	-

Secondly the correlation between the diversity indices and the number of Red List species was analysed in order to identify the effect of uniqueness on the indices (Table 23). This correlation is generally low. The number of Red List species does not appear to be correlated with any of the indices, although for birds there seems to be some correlation with species richness (0.71).

Table 23: Correlation (r) between diversity indices and Red List species.

Correlation coefficient (r) (Ind:Red List)	Richness	Shannon index	Evenness	Simpson	evenness
Birds	0.71	0.31	0.17	0.42	0.12
Insect species	0.47	0.31	0.16	0.41	0.04
Fish	0.52	0.52	0.50	0.36	0.31
Higher plants	0.59	0.50	0.43	0.46	-
Lichens	0.57	0.54	0.44	0.46	-

Thirdly we looked at the correlation between the indices and the degree of naturalness for vascular plants (Table 16). Appendix 5 shows the degree of naturalness, based on the forest management regime. When we assume that the most biologically complete situation is the most natural situation (with natural dynamics or disturbance), then we expect that this undisturbed situation will give high diversity values compared to disturbed situations of the same vegetation type. This should result in a correlation between degree of naturalness and the different diversity indices. The analysis however shows that this correlation is very low and negative, varying between –0.15 and –0.32. This may be explained by the fact that the disturbance is relatively low, compared to more temperate or Atlantic forest types.
However, the assesment of disturbance was done afterwards, based on field notes, and is probably not reliable enough for this assessment. The results may therefore not be very trustworthy.

Considering all these less visible connotations with the diversity indices (See Appendix 6 for a summary per MODIS class), and slight differences, which are hard to explain from species diversity, it may be better to use species richness. Shannon and Simpson's diversity index are often much correlated, and should not be used together with species richness. The inventory method has much influence on these indices (see in particular the birds), and for some species groups like mammals and herpetofauna the observations did not allow the calculation of these indices. Species richness may therefore be more straightforward and easy to use, in combination with Red List species.

6.3 Conclusions methodology

It is clear that looking at species numbers only does not give much information on biodiversity in the sense of community diversity and its numerical structure. Just having many species does not imply a natural ecosystem and does not guarantee the presence of rare species. The use of other measures may assist in the process to quantify what we might consider 'valuable nature'. Mathematical indices such as the Shannon and Simpson index are largely influenced by simple species richness, the inventory method and size of the area. Besides, comparison between taxa is very difficult, due to different inventory methods and results. The indices do therefore not add much to the species number, which is a straight-forward indicator.

In this study the biodiversity has been quantified with the help of these biodiversity indices, but also with species richness, number of Red List species present in a certain area and the naturalness of the forest. The results show that different Land Units are of importance to each group.

Some indicator species (for liches or vascular plants) could be selected, but this would require further study to assess their suitability.
Dead wood is insufficiently assessed, to implement the indicator at this stage of the project.

The relationship between biodiversity parameters and e.g. abiotic variables like soil type, disturbance factor, landscape zone, position of the community in the landscape etc. have thus far not been analysed. This would definitely require a much more thorough assessment in a following phase of this project.

6.4 Integrated assessment of biodiversity in PRISM

We have assessed in this study the suitability of indicators, and those indicators which are thought most relevant at this stage are:

At stand level, or local level:
- indicator species
- species diversity
- species rarity (e.g. number of Red List, rare, protected or endemic species)
- dead wood

At river basin / ecosystem level:
- ecosystem rarity
- minimum area size / landscape pattern (fragmentation measure)
- naturalness

Note that some of the indicators mentioned could not be assessed, due to missing data or maps. They are however complementary to the general indicators like e.g. species diversity, and should therefore still be worked out in a later stage.

The indicators listed above can possibly also be combined and integrated in one measure of biodiversity. However, at this stage part of the data is not available yet to implement this for the project since maps are lacking or further analysis is required for naturalness (N), minimum area requirements (MA), and dead wood (DW).
An integrated algorithm could have the following set-up for the Biodiversity Value (B_{tax}) for each taxon:

$$B_{tax} = \frac{DI + R + DW + N + MA + Er}{5}$$

in which:
DI = species diversity (species richness; stand level)
R = rarity (number of Red-List species, protected species, endemism)
DW = Dead wood (volume, m^3)
N = naturalness (i.e. rate of disturbance)
MA = meeting requirements for Minimum Area size (fauna)
ER = Ecosystem rarity

The B_{tax} can be compiled for different ecosystems on the basis of values for all relevees. Based on the available field data we can define for every relevé or sampled area and for every taxon an integrated measure for biodiversity. For all the taxa we can then come to an assessment of biodiversity for different ecosystems.

At this stage, it is not possible yet to calculate it, due to relevant data which is lacking for several indicators, e.g. the DW, N, and MA are currenlty unknown, or maps are lacking to assess these parameters.

6.5 Biodiversity link with forestry model

The value of the relevés is linked to the Land Unit (Table 9, Table 18, Table 19, appendix 4). The approach where species richness was related to the Land Unit gave satisfactory results (§ 4.4).

To make the measure of biodiversity more appropriate, a temporal analysis is required, in which the rate of disturbance is taken into account and the change in biodiversity over time, as a result of restoration of natural dynamics, and vegetation succession.
The general diversity assessment which is developed here can then be linked to a model in which changes over time are shown. The vegetation types should be given a temporal aspect, vegetation development and succession series should be developed for each Land Unit, with the related conservation value for the Land Unit. An example is given for the forest units, relating the disturbance class (appendix 5) to diversity value (Figure 27). We see in the trendline how biodiversity increases with a decrease in disturbance.

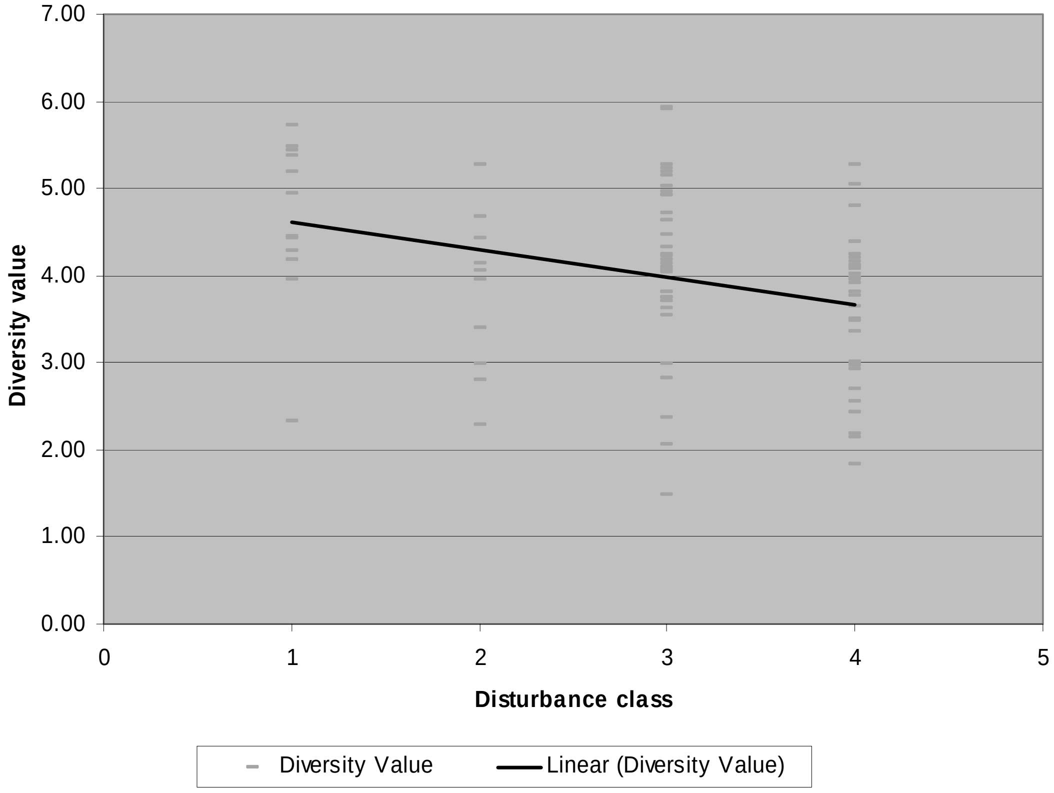

Figure 27: Example, relation between diversity value and disturbance class; 0 = limited disturbance, 5 = heavily modified

Series should be developed for all Land Units, with an assessment of change in biodiversity over time. These series are very important for further spatial modelling of ecosystem processes and land use management, to predict effects of management interventions on land use (pattern) and biodiversity (value).

In Figure 28 we see how the defined forest management interventions are related to every Land Unit. The database holds information on every Land Unit regarding its development, and concurrent development of vegetation structure and biodiversity. Based on these data the change in value and changes in vegetation structure is predicted, and via feed-back loops this possibly leads to new or adjusted management interventions.

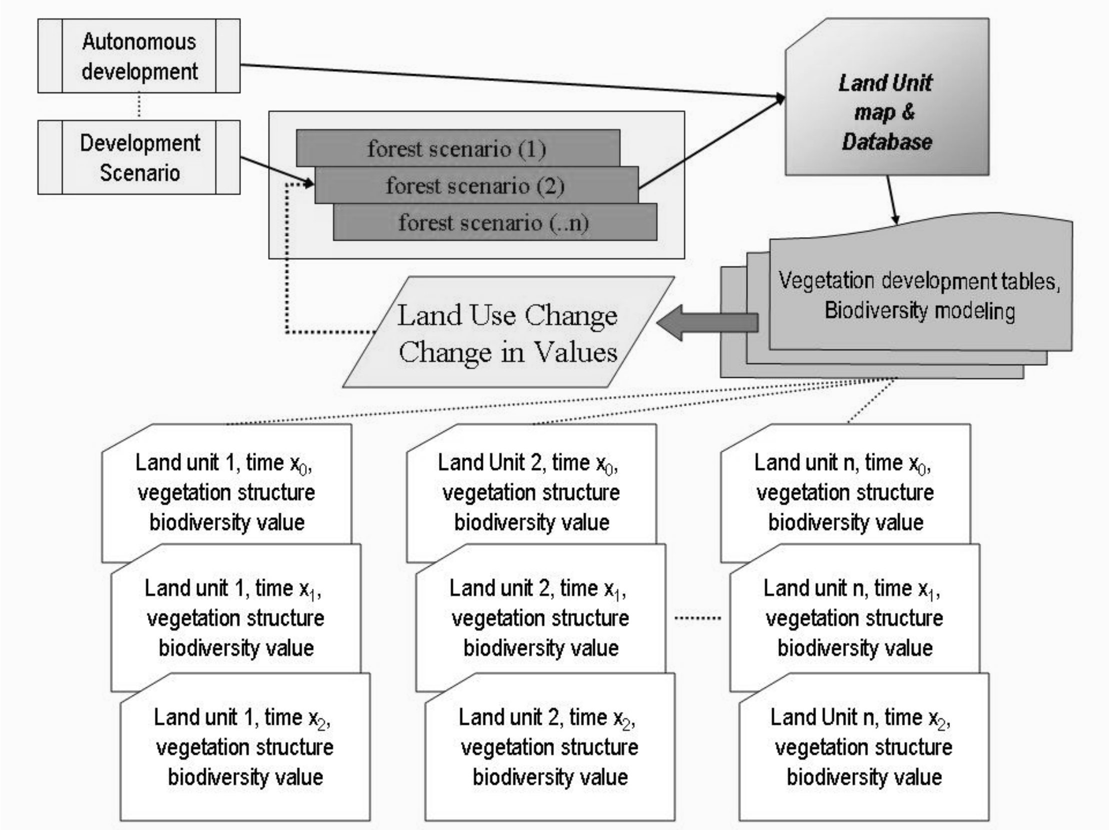

Figure 28: schematic presentation of interactions in modelling

At present we still lack detailed information about the land use history, and how this directly affects the vegetation structure development and biodiversity.
In this study we made a start of this analysis, based on available data of fieldwork. However, more correlative research is required in this respect, whereby past management measures are evaluated in respect of their effect on the biodiversity.

As much as that forestry modelling is region-specific, also biodiversity modelling should be region specific and relative to local condiitions. The differences in diversity in the North and South are obvious, and extrapolation on a scale of the River Basin may in fact result in gross errors. Sampling in a similar way for the entire area is therefore essential to come to acceptable results basin wide.

Specific land units in the MODIS classification should be more refined, in particular the aquatic ecosystems, which are currently all combined in the land cover type 'water'.

Literature

Angelstam, P., Majewski, S. Bondrup-Nielsen, 1995. *West-east cooperation in Europe for sustainable boreal forests.* Water, Air and soil pollution (82) 1-2: 3-11.

Angelstam, P., Anufriev, V., Balciauskas, L., Blagovidov, A., Borgegård, S-O., Hodge, S., Majewski, P., Shvarts, E., Tishkov, A., Tomialojc, L, , Wesolowski, L., 1997. *Biodiversity and sustainable forestry in European forests - how west and east can learn from each other.* Wildlife Society Bulletin 25(1): 38-48.

Angelstam, P., 1998. Maintaining and Restoring Biodiversity in European Boreal Forests by Developing Natural Disturbance Regimes. J. of Vegetation Science, no. 9, pp. 593-602.

Angelstam, P., 1999. Reference Areas as a Tool for Sustaining Forest Biodiversity in Managed Landscapes. Naturschutzreport, 19.

Bachmann, P, M. Kohl, R. Paivinen (eds), 1998. Assessment of Biodiversity for Improved Forest Planning: Proceedings of the Conference on Assessment of Biodiversity for Improved Planning, 7-11 October, Monte Verita, Switzerland. EFI Proceedings no. 18 (Forestry Sciences, Vol 51)

Barendregt, A., & J. Dagevos, 2003. Natuurwaardering terug van weggeweest. Landschap 20: 15-25.

Bratsev, A.A., 2002. *Hydrology.* Chapter. 3 in Ponomarev et al., 2004.

Buryan, M.V., 2002. Socio-economic characteristics of the Pechora Basin districts. Chapter 2 in Ponomarev et al., 2004.

CBD, 1997. *Indicators of forest diversity.* Working document prepared for the meeting of the liaison group on forest biological diversity. UNEP/CBD/SBSTTA/3/Inf.23, Montreal, Canada. Secretariat of the convention on Biological Diversity.

CBD, 2003. *Monitoring and Indicators: Designing national-level monitoring programmes and indicators.* Ninth Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice. Report UNEP/CBD/SBSTTA/9/10, Montreal, Canada, Secretariat of the convention on Biological Diversity.
http://www.biodiv.org/doc/meetings/sbstta/sbstta-09/official/sbstta-09-10-en.pdf

Clausman, P.H.M.A., W. van Wijngaarden & A.J. den Held, 1984. *Verspreiding en ecologie van wilde planten in Zuid Holland.* Deel A: Waarderingsparameters. Provinciale Planologische Dienst Zuid-Holland.

Dale, V.H., S. Brown, R.A. Haeuber, N.T. Hobbs, N. Huntly, R.J. Naiman, W.E. Riebsame, M.G. Turner, and T. J. Valone, 2000. *ESA Report. Ecological principles and guidelines for managing the use of land.* Ecological Applications 10:639-670.

De Groot, R.S., 1992. *Functions of Nature: evaluation of nature in environmental planning, management and decision-making.* Wolters Noordhoff BV. Groningen. 345 pp.

Degteva, S.V., 2002. *Protected nature areas*. Chapter 20 in Ponomarev *et al.*, 2004.

Degteva, S.V., 2004. *Vegetation analysis and ecosystem processes, human impact assessment.* Syktyvkar, Institute of Biology, Komi Science Centre, Russia

De Heer, M., V. Kapos, B. ten Brink (in press). *Biodiversity trends and threats in Europe. Development and test of a species trend indicator.* Technical report, UNEP World Conservation Monitoring Centre and Netherlands Environmental Assessment Agency RIVM. Netherlands.

Den Hollander, H. & M. van Eerden, 2004. MODIS classification…...

EEA, 2004. An inventory of biodiversity indicators in Europe. Technical rep. no. 92, EEA, Luxembourg.

Enoksson, B., P. Angelstam, K. Larsson, 1995. Deciduous forest and resident birds: the problem of fragmentation within a coniferous forest landscape. Landscape Ecology 10: 267-275

FAO, 2003. *Biodiversity and the ecosystem approach in agriculture forestry and fisheries.* FAO-report, Rome.

Foppen, R., 2001. *Bridging gaps in fragmented marshlands.* Alterra scientific contributions 4, Wageningen, The Netherlands.

Fukarek, F., 1980. Über die Gefährdung der Flora der Nordbezirke der DDR. Phytocoenologia 7:174-182

Groot Bruinderink, G., T. van der Sluis, D. Lammertsma, P. Opdam, R. Pouwels, 2003. *Designing a coherent ecological network for large mammals in Northwestern Europe.* Conservation Biology 17 (2): 1-9.

Hennekens, S.M., 1995. *TURBO(VEG). Software package forinput, processing, and presentation of phytosociologicaldata.* User's guide. Instituut voor Bos en Natuur,Wageningen and Unit of Vegetation Science, Universityof Lancaster, Lancaster.

Hennekens, S.M. & J.H.J. Schaminée, 2001. *TURBOVEG, a comprehensive data base management system.* Journal of Vegetation Science 12: 589-591, Hertog, A.J., & M. Rijken, 1992. G*eautomatiseerde bepaling van natuurbehoudswaarde in vegetatie-opnamen*. Dienst Ruimte, wonen en groen, Provincie Gelderland, Netherlands.

Hunter, M.L., 1996. *Fundamentals of conservation biology*. Blackwell Science, Cambridge, Massachusetts.

Huston, M.A., 1994. Biological diversity – the coexistence of species on changing landscapes. Cambridge university press, Cambridge, UK.

IUCN, UNEP & WWF, 1991. *Caring for the Earth. A strategy for sustainable living.* IUCN, UNEP and WWF, Gland, Switzerland, and Earthscan, London

Ivits, E., B. Koch, (undated). Object-oriented remote sensing tools for biodiversity assessment: a European approach. Paper published on internet, 8 p.

Jenkins, M. & D. Williamson, 2003. *Effectiveness of biodiversity conservation.* In: Biodiversity and the ecosystem approach in agriculture forestry and fisheries, p. 102-116. FAO-report, Rome.

Jonsson, B.G., M. Jonsell, 1999. *Exploring potential biodiversity indicators in boreal forests.* Biodiversity and Conservation 8: 1417-1433.

Jorritsma, I., A.F.M. Van Hees, & G.M.J. Mohren, 1999. *Forest development in relation to ungulate grazing: a modeling approach.* Forest ecology and management, Vol. 120 Issue 1-3, p. 23-34.

Kiessling, W., 2005. Long-term relationships between ecological stability and biodiversity in Phanerozoic reefs. Nature 433, 410 – 413.

Kolesnikova, A., T. van der Sluis, (in prep). The structure diversity of soil invertebrates in the Pechora river basin

Kozubow, G.M., & A.I. Taskaev, (Ed.), 2000. *Forestry and forest resources in the Komi Republic* (In Russian). Institute of Biology, Komi Science Centre, Ural Division, Russian Academy of Sciences. Design Information, Cartography Moscow.

Kuzmin, 1995.Die Amphibien Rußlands und angrenzender Gebiete. Westarp Wissenschaften. Neue Brehm Bücherei, Spektrum Akademischer Verlag.

Larsson, T.-B., 2001. Biodiversity evaluation tools for European forests. Ecol. Bull. 50

Leummens, H., V. Ponomarev, T. van der Sluis (eds.), 2002. Prism / NWO progress report 2002, Part II – Upstream expedition Bolshaya Synya area. RIZA, Lelystad.

Leummens, H., V. Ponomarev, T. van der Sluis (eds.), 2003. *Prism / NWO progress report 2002, Part II – Expedition Vel`yu & Upper Pechora.* RIZA, Lelystad.

Lindenmayer, D.B., 1999. Future directions for biodiversity conservation in managed forests: indicator species, impact studies and monitoring programs. Forest ecology and management 115: 277-287

Londo, G., G. van Wirdum, 1994. *Natuurlijkheidsgraden en natuurontwikkeling.* De Levende Natuur 95 (1): 10-16.

Machado, A., 2004.*An index of naturalness.* Journal for nature conservation 12: 95-110.

Margiocco, C. & M. Mariotti, 2001. *Basi di dati e cartografia dellabiodiversità.* Rapporto finale parte italiana. Consenza, Italy.

Margules, C. and M. B. Usher, 1981. Criteria used in assessing wildlife conservation potential: a review. Biol. Conserv. 21:79-109.

McArthur, R.H. & E.O. Wilson, 1967. *The theory of island biogeography*, Princeton University Press, 203 p.

McGarigal, K. & B. Marks, 1995. *Fragstats: spatial pattern analysis program for quantifying landscape structure.* Gen Tech. Rep. PNW-GTR-351. US Dep. of Agriculture, Forest Service, Pacific Northwest research station, Portland, OR, USA.

Musters, C.J.M., J.N.M. Dekker & W.J. ter Keurs, 2002. Wordt de natuur wel de goede maat genomen? Landschap 19: 135-151.

Newton, A.C. & V. Kapos, 2002. *Biodiversity indicators in national forest inventories.* Forest drylands and freshwater programmes, UNEP World Conservation Monintoring centre (WCMC), Cambridge, UK; http://sea.unep-wcmc.org/collaborations/BINU/working docs/indicator/Forest%20Indicators%20Unasylva.doc.

Noss, R.F., 1990. *Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology, 4(4): 355-364.*

Noss, R.F., 1999. Assessing and monitoring forest biodiversity: a suggested framework and indicators. Forest ecology and management, 115: 135-146

Noss, R. F., A.Y. Cooperrider, 1994. Saving nature's legacy: protecting and restoring biodiversity. Washington, DC, Island Press, USA.

Noss, R. F., M. A. O'Connell & D. A. Murphy, 1997. The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act. Washington, Island Press, USA.

Ponomarev, V, O. Loskutova, L. Khokhlova, H. Leummens, 2004. *The Pechora river: a natural functioning river ecosystem, or needs for restoration?* Proceedings 3rd European conference on River restoration. Zagreb, Croatia, May 2004.

Ponomarev, V., M. Munsterman, & H. Leummens, 2004. The Pechora River Basin. Russian Academy of Sciences, Ural division, Komi Science Centre, Institute of Biology & Ministry of Transport, public works & water management RIZA. Syktyvkar, Russia – Lelystad, The Netherlands

Ritters, K., J. Wickham, R. O'Neill, B. Jones, and E. Smith, 2000. *Global-scale patterns of forest fragmentation.* Conservation Ecology 4(2): 3. [online] URL: http://www.consecol.org/vol4/iss2/art3

Reijnen, R, (ed.), 1998. *Graadmeters voor terrestrische biodiversiteit.* Werkdocument 1998/02, DLO Natuurplanbureau onderzoek, IBN-DLO/SC-DLO, Wageningen, Netherlands

Shaffer, M.L., 1981. Minimum population sizes for species conservation. BioScience 31:131-134

Simpson, E. H., 1949. *Measurement of diversity.* Nature 163:68

Spellerberg, I. F., 1992. Ecological evaluation for conservation. Chapman & Hall, London, UK

Ståhl, G. & T. Lämås, 1996. Assessment of coars woody debris. A comparison of probability sampling methods. In: Bachman et al.

Taiga rescue network, 1999. The last of the last: The Old-growth Forests of Boreal Europe. http://www.forest.ru/eng/publications/last/maps/komi.html

Taskaev, A.I., (ed.), 1998. Red Data book of the Komi Republic. Rare and endangered species of animals and plants. D&K, Syktyvkar, Russia.

Ten Brink, B., van Strein, & R. Reijnen, 2001. *De natuur de maat genomen in vier graadmeters.* Landschap 18: 5-20.

Uliczka, H. & Angelstam, P., 2000. Assessing conservation values of forest stands based on specialised lichens and birds. Biological Conservation 95: 343-351

Usher, M.B., 1986. *Wildlife conservation evaluation.* Chapman & Hall, Cambridge, UK.

Van der Sluis, T., 1996. *Vegetatiekundige Natuurwaardebepaling.* IBN-Report Natuurontwikkeling No. 7.

Van der der Sluis, T., M. Bloemmen and I.M. Bouwma, 2004. *European corridors: strategies for corridor development for target species.* ALTERRA, ECNC, ISBN: 90-76762-16-3. Tilburg/Wageningen, The Netherlands.

Van der Sluis, T., S. Degteva, G.B.M. Pedroli (in press). *The Pechora River (Russia): the last untouched European River.* Journal of River Basin Management.

Van der Sluis, T., S. Degteva, P. Slim, B. Pedroli (in press). *Towards biodiversity assessment for boreal forests in the Pechora River Basin (Russian Federation).* Proceedings IUFRO conference on forest biodiversity, Firenze, Italy (In Press).

Van Eerden, M.R. (ed.), 2000. *Pechora Delta. Structure and dynamics of the Pechora Delta ecosystems (1995-1999).* RIZA-report nr. 2000.037. Institute of Biology/State Committee for Environmental Protection of Nenets Autonomous Okrug/RIZA, Lelystad, The Netherlands.

Wamelink, G.W.W., C.J.F. ter Braak, H.F. van Dobben, 2003. *Changes in large-scale patterns of plant biodiversity predicted from environmental economic scenarios.* Landscape Ecology 18:513-227.

WCMC, 1992. Global biodiversity: status of the Earth's living resources. Chapman and Hall, London. 585 p.)

Welk, E., 2002. *Arealkundliche analyse und Bewertung der Schutzrelevanz seltener und gefährdeter Gefäßpflanzen Deutschlands.* Schriftenreihe fur Vegationskunde, Heft 37.Bundesamt fur Naturschutz, Bonn, Bad Godesberg, Germany.

Whittaker, R.H., 1972. Evolution and measurement of species diversity. Taxon, 21, 213-251.

Wohlgemuth T., M. Bürgi, C. Scheidegger, M. Schütz, 2002. *Dominance reduction of species through disturbance – a proposed management principle for central European forests.* Forest ecology and management, Vol. 166: 1-15.

Appendix 1 Land Units of the Pechora Basin

	Vegetation Formation/Ecotope	Vegetation type	code	Land Unit
Forest	Pine forest (>70%)	pine, Greenmoss type	1.1	FPg
		pine, Lichen type	1.2	FPl
		pine, Haircap moss	1.3	FPp
		pine, Sphagnum type	1.4	FPs
	Spruce/Fir forest (>70%)	spruce, Greenmoss	2.1	FSg
		spruce, Haircap moss (Pol. Comm)	2.2	FSp
		spruce, Sphagnum	2.3	FSs
		spruce, Herb type	2.4	FSh
	Aspen forest (>70%)	aspen, Greenmoss	3.1	FAg
		aspen, Herb type	3.2	FAh
	Birch forest (>70%)	birch, Greenmoss	4.1	FBg
		birch, Lichen	4.2	FBl
		birch, Haircap moss (Pol. Comm)	4.2	FBp
		birch, Sphagnum	4.3	FBs
		birch, Herb type	4.4	FBh
	Willow forest (>70%)	shrubs and trees	5.1	FWs
	Mixed forest	pine dominated	6.1	FMp
		spruce/Fir dominated	6.2	FMs
		aspen dominated	6.3	FMa
		birch dominated	6.4	FMb
		willow dominated	6.5	FMw
	Disturbed forest	clearcut, greenmoss type	7.1	FDg
		clearcut, lichen type	7.2	FDl
		clearcut, moss type	7.3	FDm
		clearcut, sphagnum type	7.4	FDs
		burnt area	7.5	FDb
Mountain, tundra	Mountain	bare rock	8.1	XMb
		glacier, snow	8.2	XMg
		mountain tundra	8.3	XMt
		fir forest	8.4	XMf
		open forest mosaic	8.5	XMm
	Northern tundra	dwarf shrub-lichen	8.6	XNl
		dwarf shrub-small hummock-moss	8.7	XNh
		cotton grass-sphagnum	8.8	XNc
	Southern tundra	willow-birch shrub, open, graminoid	8.9	XSo
		willow-birch shrub, closed	8.10	XSc
		bog tundra	8.11	XSw
		forest tundra mosaic	8.12	XSf

CONTINUED, pto

	Vegetation Formation/Ecotope	Vegetation type	code	Land Unit
Fe ns and bogs	Fens & bogs	rich fen	9.1	XFf
		tall sedges marsh	9.2	XFc
		transitional bog	9.3	XFt
		poor fen, sphagnum bog	9.4	XFs
		wooded bog	9.5	XFw
Water & shore	River	main course	10.1	WRm
		small river, creek	10.2	WRs
		oxbow, connected	10.3	WRc
		oxbow, disconnected	10.4	WRd
		sandbank	10.5	WSs
		gravel bank	10.6	WSg
	Lake	river Lake	10.7	WLr
		mountain Lake	10.8	WLm
		tundra Lake	10.9	WLt
		peat bog lake	10.10	WLp
	Coastal	marine	10.11	WCm
		large bay	10.12	WCl
		lagoon & tidal brackish	10.13	WCt
		freshwater riverine	10.14	WCf
		dunes	10.15	WSd
		tidal flats	10.16	WSt
		coastal meadow	10.17	WSm
		coastal river delta	10.18	WSr
	Floodplains	meadows, natural grassland	10.19	WGn
Anthropogenic	Grassland	meadows, grazed	11.1	AGg
		meadows, haylands	11.2	AGh
		meadows, abandoned	11.3	AGa
	Anthropogenic	urban area	12.1	AAu
		gardens, ruderal communities	12.2	AAr
		drainage, ditch	12.3	AAd
		infrastructure	12.4	AAi

Appendix 2 Rare vascular plants NPA 'Virgin forests Komi'

Вид	Status		
	Red Data Book Komi Republic[1]	Red Data Book of Russia	Red List of IUCN
Botrichium lanceolatum (S.G. Gmelin) Angstr.	3 – R		
Botrichium matricariifolium A. Br. ex Koch	4 – I		
Botrichium boreale Milde	3 – R		
Botrichium virginianum (L.) Sw.	5 – Cd		
Woodsia alpina (Bolt.) S.F. Gray	3 – R		
Woodsia glabella R. Br.	5 – Cd		
Woodsia ilvensis (L.) R. Br.	5 – Cd		
Rhizomatopteris sudetica (A.Br. & Milde) A. Khokhr.	3 – R		
Polystichum lonchitis (L.) Roth	3 – R		
Dryopteris cristata (L.) A. Gray	3 – R		
Dryopteris filix-mas (L.) Schott	3 – R		
Dryopteris fragans (L.) Schott	3 – R		
Thelepteris paluatris Schott	3 – R		
Asplenium ruta muraria L.	3 – R		
Asplenium viride Huds	5 – Cd		
Cryptogramma crispa (L.) R. Br.	3 – R		
Cryptogramma stelleri (S.G. Gmelin) Prantl	2 – V		
Pteridium aquilinum (L.) Kuhn	2 – V		
Polypodium vulgare L.	3 – R		
Pinus sibirica Du Tour	2 – V		
Adonis sibirirca Patrin ex Ledeb.	1 – E		
Thalictrum alpinum L.	5 – Cd		
Thalictrum aquilegifolium L.	3 – R		
Anemonoides altaica (C.A. Mey) Holub	3 – R		
Anemone sylvestris L.	5 – Cd		
Anemonoides ranunculoides (L.) Holub	3 – R		
Anemonastrum biarmiense (Juz.) Holub	2 – V		
Ranunculus hyperboreus Rottb.	5 – Cd		
Ranunculus lingua L.	3 – R		
Ranunculus pallasii Schlecht.	3 – R		
Ranunculus pygmaeus Wahlb.	5 – Cd		
Ranunculus sulphureus C.J. Phipps.	5 – Cd		
Oxygraphis glacialis (Fisch.) Bunge	4 – I		
Pulsatilla patens (L.) Mill.	2 – V		
Ficaria verna Huds.	3 – R		
Papaver lapponicum ssp. jugoricum (Tolm.) Tolm.	2 – V		
Corydalis bulbosa (L.) DC	5 – Cd		
Corydalis capnoides (L.) Pers.	5 – Cd		
Gastrolychnis involucrata (Cham. & Schlecht.) A. & D. Love	3 – R		
Dianthus repens Willd.	5 – Cd		
Gypsophila uralensis Less.	2 – V		
Minuartia rubella (Wahl.) Hiern.	5 – Cd		
Steris viscaria (L.) Rafin.	3 – R		
Silene acaulis (L.) Jacq.	5 – Cd		
Silene pauciflora Ledeb.	5 – Cd		

---

[1] Taskaev (1998)

Вид	Status		
	Red Data Book Komi Republic[1]	Red Data Book of Russia	Red List of IUCN
Silene pepens Patrin.	5 – Cd		
Cerastium krylovii Schischk. & Gorczak.	4 – I		
Cerastium regelii Ostenf.	4 – I		
Armeria scabra Pall. ex Schult.	3 – R		
Paeonia anomala L.	2 – V		
Viola collina Bess	5 – Cd		
Viola mautitii Tepl.	5 – Cd		
Viola selkirkii Pursh ex Goldie	5 – Cd		
Alyssum obovatum (C.A. Mey.) Turcz.	3 – R		
Erysimum pallasii (Pursh) Fern.	4 – I		
Draba alpina L.	5 – Cd		
Draba cinerea Adams	5 – Cd		
Draba lactea Adams	3 – R		
Draba pauciflora R. Br.	4 – I		
Achorophragma nudicaule (L.) Sojak	3 – R		
Neotorularia humilis (C.A. Mey.) Hedge & J. Leonard	4 – I		
Cardamine bellidiflora L.	3 – R		
Schiverekia podolica (Bess.) Andrz. ex DC.	3 – R	+	
Eutrema edwardsii R. Br.	3 – R		
Harrimanella hypnoides (L.) Cov.	5 – Cd		
Cassiope tetragona (L.) D. Don.	5 – Cd		
Loiseleuria procumbens (L.) Desv.	5 – Cd		
Phyllodice caerulea (L.) Bab.	5 – Cd		
Diapensia lapponica L.	5 – Cd		
Primula pallasii Lehm.	3 – R		
Rhodiola rosea L.	2 – V		
Rhodiola quadrifida (Pall.) Fisch. & C.A. Mey.	3 – R		
Saxifraga oppositifolia L.	3 – R		
Chrysosplenium tetrandrum (Lund ex Malmgr.) Th. Fries	4 – I		
Dryas octopetala L.	5 – Cd		
Dryas punctata Juz.	5 – Cd		
Cotoneaster melanocarpus Fisch. ex Blytt.	5 – Cd		
Cotoneaster uniflorus Bunge	5 – Cd		
Pentaphylloides fruticosa (L.) O. Schwarz	2 – V		
Potentilla chrysantha Trev.	4 – I		
Potentilla erecta (L.) Rausch.	5 – Cd		
Acomastylis glacialis (Adams) A. Khokhr.	3 – R		
Astregalus gorodkovii Jurtz.	4 – I		
Astregalus norvegicus Grauer	5 – Cd		
Hedisarum alpinum L.	5 – Cd		
Hedisarum arcticum B. Fedtsch.	5 – Cd		
Lotus peczoricus Min. & Ulle	2 – V		
Oxytropis mertensiana Turcz.	3 – R		
Oxytropis uralensis (L.) DC.	4 – I		
Lathyrus tuberosus L.	3 – R		
Epilobium davuricum Fisch. ex Hornem.	5 – Cd		
Epilobium montanum L.	5 – Cd		
Linum boreale Juz.	2 – V		
Phlojodiocarpus villosus (Turcz. Ex Fisch. & C.A. Mey) Ledeb.	3 – R		
Seseli condensatum (L.) Reichenb.	3 – R		

Вид	Status		
	Red Data Book Komi Republic[1]	Red Data Book of Russia	Red List of IUCN
Sambucus racemosa 2 – V	2 – V		
Gentianopsis doluchanovii (Grossh.) Tzvel.	3 – R		
Gentianella amarella (L.) Boern.	3 – R		
Galium intermedium Schult.	4 – I		
Polemonium boreale Adams	5 – Cd		
Hakelia deflexa (Wahlenb.) Opiz	3 – R		
Castilleja arctica ssp. vorkutensis Rebr.	3 – R	+	
Castilleja hyparctica Rebr.	3 – R		
Pedicularis amoena Adams ex Stev.	3 – R		
Pedicularis uralensis Wed.	3 – R		
Boschniakia rossica (Cham. & Schlecht)	3 – R		
Pinguicula villosa L.	3 – R		
Thymus talijevii Klok. et Shost.	2 – V		
Campanula persicifolia L.	1 – E		
Arnica iljinii (Maguire) Iljin	3 – R		
Aster alpinus L.	5 – Cd		
Cirsium helenioides (L.) Hill.	4 – I		
Inula salicina L.	5 – Cd		
Dendranthema zavadskii (Herbich) Tzvel.	2 – V		
Scorzonera glabra Rupr.	2 – V		
Antennaria lanata (Hook.) Greene	3 – R		
Tephroseris heterophylla (Fisch.)Konechn.	5 – Cd		
Tephroseris tundricola (Tolm.) Holub	4 – I		
Erigeron silenifolius (Turcz.) Botsch.	4 – I		
Endocellion sibiricum (J.F.Gmel.) Toman	3 – R		
Artemisia borealis Pall.	3 – R		
Artemisia sericea Web.	3 – R		
Trommadorfia maculata (L.) Bernh.	3 – R		
Crepis chrysanrtha (Ledeb.) Turcz.	5 – Cd		
Potamogeton trichoides Cham. & Schlecht.	5 – Cd		
Potamogeton filiformis Pers.	5 – Cd		
Gagea samoedorum Crossh.	5 – Cd		
Allium angulosum L.	5 – Cd		
Cypripedium calceolus L.	2 – V	+	+
Cypripedium guttatum Sw.	2 – V		
Hammarbya paludosa (L.)	3 – R		
Epipactis atrorubens (Hoffm. ex Bernh.) Bess.	2 – V		
Epipactis helleborine (L.) Crantz.	3 – R		
Calypso bulbosa (L.) Oakes	2 – V	+	
Leucorchis albida (L.) E. Mey.	5 – Cd		
Platanthera bifolia (L.) Rich.	5 – Cd		
Malaxis monophyllos (L.) Sw.	3 – R		
Dactylorhiza cruenta (O.F. Muell.) Soo	3 – R		
Dactylorhiza fuschsii (Druce) Soo	5 – Cd		
Dactylorhiza incarnata (L.) Soo	2 – V		
Dactylorhiza maculata (L.) Soo	5 – Cd		
Dactylorhiza traunsteineri (Saut.) Soo	2 – V	+	
Juncus stigius L.	4 – I		
Eleocharis quinqueflora (F.X.Hartm.)O.Schwartz	4 – I		
Eleocharis mamillata Lindb. fil.	4 – I		
Kobresia myosuroides (Vill.) Flori	4 – I		
Kobresia simpliciuscula (Wahlenb.) Mackenz.	4 – I		
Carex alba Scop.	5 – Cd		

Вид	Status		
	Red Data Book Komi Republic[1]	Red Data Book of Russia	Red List of IUCN
Carex bergrotii Palmgr.	4 – I		
Carex glacialis Mackrenz.	5 – Cd		
Carex obtusata Liljebl.	5 – Cd		
Carex pediformis C.A. Mey.	5 – Cd		
Carex williamsii Britt.	4 – I		
Carex caucasica Stev.	4 – I		
Carex krausei Boeck.	4 – I		
Carex marina Dew.	4 – I		
Carex mollissima Christ.	4 – I		
Carex atrofusca Schkuhr	4 – I		
Carex atrata L.	4 – I		
Rhynchospora alba (L.) Vahl	3 – R		
Vahlodea atropurpurea (Wahlenb.) Fries	3 – R		
Brachypodium pinnatum (L.) Beauv	5 – Cd		
Alopecurus glaucus Less.	4 – I		
Glyceria fluitans (L.) R. Br.	3 – R		
Poa urssulensis Trin.	4 – I		
Festuca pseudodalmatica	4 – I		
Agrostis korchaginii Senjan.-Korcz.	3 – R		
Elytrigia reflexiaristata (Nevski) Nevski	3 – R		
Schizachne callosa (Turcz. ex Griseb.)	3 – R		
Koeleria pohleana (Domin) Gontsch.	4 – I		
Cinna latifolia (Trev.) Griseb.	5 – Cd		
Elymus transbaicalensis (Nevski) Tzvel.	4 – I		

Appendix 3 Rare mosses NPA ‘Virgin forests Komi’

Вид	Status		
	Red Data Book of the Komi Republic[2]	Red Data Book of Russia	Red Data Book of European mosses
Sphagnum platyphullum (Lindb. Ex Braithw.) Sull. Ex Warnst.	3 – R		
Sphagnum pulchrum (Lindb. Ex Braithw.) Warnst.	3 – R		
Atrichum undullatum (Hedw.) P. Beauv.	3 – R		
Polytrichum formosum Hedw.	3 – R		
Ditrichum pusillum (Hedw.) Hampe	5 – Cd		
Polytrichum sexangukare Brid.	3 – R		
Brachydontium trichoides (Web.) Milde	3 – R		
Cnestrum alpestre (Wahlenb.) Nyh. ex Mogensen	3 – R		
Cynodontium bruntonii (Sm.) B.S.G.	4 – I		
Cynodontium fallax Limpr.	3 – R		
Dicranella schreberiana (Hedw.) Hilp. ex Crum et Anderson	5 – Cd		
Dicranum drummondii C. Muell.	3 – R		
Dicranum viride (Sull. ex Lesq.) Lindb.	2 – V		+
Kiaeria blyttii (B.S.G.) Broth.	5 – Cd		
Paraleucobryum longifolium (Hedw.) Loeske	5 – Cd		
Bryobrittonia longipes (Mitt.) Horton	5 – Cd		
Encalypta brevicolis (B.S.G.) Aongstr.	3 – R		
Barbula unguiculata Hedw.	5 – Cd		
Didymodon rigidulus Hedw.	5 – Cd		
Grimmia unicolor Hook.	2 – V		
Hydrogrimmia mollis (B.S.G.) Loeske	3 – R		
Racomitrium aciculare (Hedw.) Brid.	3 – R		
Racomitrium fasciculare (Hedw.) Brid.	2 – V		
Funaria microstoma Bruch ex Schimp.	4 – I		
Schistostega pennata Hedw.	3 – R		+
Pohlia longicollis (Hedw.) Lindb.	3 – R		
Pohlia ludwigii (Schwaegr.) Broth.	3 – R		
Pohlia elongata Hedw.	3 – R		
Plagiomnium confertidens (Lindb. et H. Arnell) T. Kop	3 – R		+
Philonotis arnellii Husn.	3 – R		
Plagiopus oederiana (Brid.) Limpr.	5 – Cd		
Ulota curvifolia (Wahlenb.) Brid.	3 – R		
Dichelima falcatum (Hedw.) Myr.	5 – Cd		
Neckera pennata Hedw.	3 – R		+
Myurella tenerrima (Brid.) Lindb.	3 – R		
Myurella sibirica (C. Muell.) Reim.	2 – V		
Leptopterigynandrum ausro-alpinum C. Muell.	3 – R		
Lescruraea mutabilis (Brid.) Lindb.	3 – R		
Pseudoleskea incurvata (Hedw.) Lawt.	5 – Cd		
Pseudoleskea radicola (Mitt.) Kindb.	3 – R		
Pseudoleskea patens (Lind.) Kindb.	2 – V		
Pseudoleskeella tectorum (Brid.) Kindb. ex Broth.	5 – Cd		
Anomodon longifolius (Brid.) Hartm.	3 – R		
Anomodon viticulosus (Hedw.) Hook. et Tayl.	5 – Cd		

---

[2] Taskaev (1998)

Вид	Status		
	Red Data Book of the Komi Republic[2]	Red Data Book of Russia	Red Data Book of European mosses
Campylium halleri (Hedw.) Lindb.	3 – R		
Loeskypnum badium (Hartm.) Paul.	5 – Cd		
Hygrohypnum norvegicum (B.S.G.) Amann	3 – R		+
Brachythecium glareosum (Spruce) B.S.G.	5 – Cd		
Brachythecium plumosum (Hedw.) B.S.G.	5 – Cd		
Eurhynchium schleicheri (Hedw. f.) Jur.	5 – Cd		
Rhynchostegium riparioides (Hedw.) C. Jens.	5 – Cd		
Scleropodium orellanum (Mol.) Lor.	3 – R		
Orthothecium intricatum (C. Hartm.) B.S.G.	5 – Cd		
Hypnum pallescens (Hedw.) P. Beauv.	5 – Cd		
Hypnum plicatulum (Lindb.) Jaeg.	3 – R		+
Hypnum vaucheri Lesq.	5 – Cd		
Hylocomiastrum umbratum (Hedw.) B.S.G.	5 – Cd		

Appendix 4 Diversity indices for all land units

		AAd	AAi	AAr	AAu		AGa	AGg	AGh		FAg	FAh		FBg	FBh	FBl	FBp	FBs		FDb	FDg	FDl	FDm	FDs		FMa	FMb	FMp	FMs		FPg	FPl	FPp	FPs	
Birds	**Birds**																																		
	#samples		5	6			2	1	2		4	1		3	2	3				5	3	1	2	1		1	1	4	8		6	11		6	
	Species richness		45	28	19		19	4	14		22	17		24	10	24				18	15	22	6	8		13	27	53	56		38	47		32	
	Shannon index		1,68182	1,65078			1,88979	0,69315	1,0664		1,97236	2,29128		1,93887	1,63904	1,6408				1,5852	1,48421	2,48729	0,93493	1,77703		2,50666	2,3234	1,96214	2,00173		1,88092	1,75258		1,89789	
	Evenness		0,66496	0,88549			0,94753	1	0,67701		0,90463	0,80872		0,85827	0,98048	0,92447				0,97693	0,82994	0,91848	0,74962	0,85457		0,97728	0,935	0,93553	0,9301		0,94966	0,93533		0,91299	
	Simpson		7,38829	4,74078			6,29327	2	2,1785		5,98211	6,21783		5,50242	5,28571	5,00977				5,08769	3,55368	10,2558	2,05026	4,3494		11,6452	8,64286	6,87772	7,2694		6,31079	6,30938		5,83554	
	eveness		0,65798	0,71916			0,81757	1	0,44962		0,67141	0,36575		0,56812	0,94643	0,72797				0,9211	0,59048	0,68372	0,58818	0,54367		0,89578	0,72024	0,79112	0,7887		0,80552	0,81683		0,71122	
	# Red List species		**2**			**2**	**1**			**1**			**0**						**0**						**0**				**2**	**2**				**1**	**1**
Mammals	**Mammals**																																		
	#samples																																		
	Species richness		1			1	5	1		5										4					4						4	2			6
	Shannon index																																		
Herpetofauna	**Herpetofauna**																																		
	# samples																																		
	Richness	4	**2**	**1**		**4**	**1**	**1**	**2**	**3**	**1**		**1**		1				1	2		**1**	**1**	**3**	**4**				**1**	**1**				**2**	**2**
	Shannon index (H)																																		
	Evenness E (H)																																		
	Simpsons Index (D)																																		
	Eveness E (D)																																		
	# Red List species	**1**																																	
	Insects																																		
Insects	**Species**																																		
	# samples				**2**		**2**	**3**			**1**	**3**		**6**	**16**		**6**	**2**		**1**	**10**	**1**	**2**	**2**			**7**	**3**	**5**		**6**	**6**	**1**	**3**	
	Richness species		3	2	11		**28**	4	**26**		8	11		22	**48**		17	10		3	**28**	1	3	9			11	7	14		19	18	2	6	
	Shannon (H)				0		2,69	2,04			1,95	1,85		2,69	3,45		2,63	2,26		0,92	3,05	0	1,1	1,72			2,09	1,81	2,24		2,64	2,53	0,39	1,61	
	Evenness E (H)				0		0,93	0,89			0,94	0,89		0,91	0,93		0,95	0,98		0,84	0,95	0	1	0,83			0,91	0,93	0,94		0,95	0,94	0,56	1	
	Simpson (D)				1		**12,43**	6,66			5,90	5,54		**11,03**	**24,76**		11,92	9,11		2,17	**18,36**	1	3	4,41			6,68	5,62	8,38		**11,94**	9,57	1,29	5	
	Evenness E (D)				1		0,69	0,67			0,74	0,69		0,58	0,62		0,75	0,91		0,72	0,73	1	1	0,55			0,67	0,80	0,76		0,75	0,64	0,65	1	
	# Red List species													**1**					**1**																
	Genus																																		
	# samples																																		
	Richness Genus		3	2	5		9	3	**11**		5	5		6	**11**		8	3		5	8	0	3	4			7	6	**10**		8	**10**	3	7	
	Shannon (H)				0,65		0,94	1,61			1,41	1,25		1,39	1,69		1,29	0,92		1,39	1,84		0,90	0,51			1,57	1,47	1,95		1,80	1,55	0,30	0,93	
	Evenness E (H)				0,59		0,68	0,90			0,88	0,78		0,86	0,81		0,62	0,84		0,86	0,89		0,82	0,46			0,87	0,82	0,94		0,87	0,71	0,27	0,58	
	Simpson (D)				1,56		2,06	4,58			3,67	2,73		3,43	4,26		2,28	2,34		3,60	5,32		2,17	1,34			4,13	3,31	6,12		4,83	2,84	1,15	1,78	
	Evenness E (D)				0,52		0,52	0,76			0,73	0,55		0,69	0,53		0,28	0,78		0,72	0,66		0,72	0,45			0,69	0,55	0,77		0,60	0,32	0,38	0,36	
Fish	**Fish**																																		
	# samples																																		
	Richness																																		
	Shannon (H)																																		
	Evenness E (H)																																		
	Simpson (D)																																		
	Evenness E (D)																																		
	Red List Species																																		
Benthos	**Benthos Families**																																		
	# samples																																		
	Richness																																		
	Shannon (H)																																		
	Evenness E (H)																																		
	Simpson (D)																																		
	Evenness E (D)																																		
	Vegetation																																		
			AAi	**AAr**	**AAu**		**AGa**	**AGg**	**AGh**		**FAg**	**FAh**		**FBg**	**FBh**	**FBl**	**FBp**	**FBs**		**FDb**	**FDg**	**FDl**	**FDm**	**FDs**		**FMa**	**FMb**	**FMp**	**FMs**		**FPg**	**FPl**	**FPp**	**FPs**	
Higher plants	**Higher plants**																																		
	# samples		12	4		16		7	3	10	2	3	5	11	16	2	5	4	38	6	1	1	6	5	19		1	1	3	5	9	8	4	7	28
	Richness		24,75	29,00		25,81		40,57	47,67	42,70	25,00	40,00	34,00	24,09	43,69	22,50	25,60	18,75	31,89	18,00	14,00	12,00	19,67	18,60	18,16		34,00	17,00	30,00	28,20	17,11	9,50	11,75	14,57	13,54
	Max. spec.richness		46	43		46		55	61	61	26	47	47	37	56	29	45	32	56	32	14	12	24	24	32		34	17	45	45	39	14	14	18	39
	Shannon (H)		2,04	2,14		2,0625		2,87	3,55	3,08	1,98	2,39	2,22	1,99	2,46	1,78	1,91	1,81	2,15	1,71	1,55	1,09	1,86	1,80	1,74		2,02	1,55	2,14	2,00	1,52	1,09	1,22	1,65	1,39
	Evenness E (H)		0,65	0,65		0,65		0,78	0,93	0,83	0,61	0,65	0,63	0,63	0,66	0,58	0,60	0,64	0,64	0,60	0,59	0,44	0,63	0,62	0,61		0,57	0,55	0,64	0,61	0,56	0,49	0,49	0,62	0,55
	Simpson (D)		0,77	0,72		0,76		0,84	0,95	0,87	0,80	0,84	0,82	0,78	0,83	0,74	0,75	0,74	0,79	0,72	0,68	0,57	0,75	0,75	0,73		0,75	0,71	0,82	0,78	0,67	0,58	0,52	0,71	0,63
	Evenness E (D)																																		
	Red List Species		1			1		1	1	2	1	2	2	1	6				6						0			1	1	1	1	1		2	2
Mosses	**Mosses**																																		
	# samples		12	1				2	1		2	3		10	14	2	5	3		6	1	1	6	3			1	1	2		5	6	4	6	
	Richness		4,67	1				3,00	2,00		8,50	5,67		7,40	5,36	5,50	7,20	8,33		4,67	11,00	5,00	8,83	7,67			5,00	6,00	8,00		4,40	4,67	2,25	8,33	
	Shannon (H)		0,74	0				0,62	0,69		1,48	1,00		0,90	0,95	0,99	1,04	1,10		0,54	1,41	1,36	1,20	1,30			0,52	0,51	1,20		0,44	1,30	0,28	1,48	
	Evenness E (H)		0,46	0				0,38	1,00		0,69	0,59		0,45	0,69	0,57	0,53	0,51		0,36	0,59	0,84	0,53	0,67			0,32	0,28	0,57		0,30	0,89	0,24	0,70	
	Simpson (D)		0,38	0				0,35	0,50		0,68	0,47		0,40	0,49	0,46	0,49	0,50		0,24	0,64	0,68	0,50	0,57			0,22	0,20	0,54		0,21	0,67	0,16	0,69	
	Evenness E (D)																																		
	Red List Species																																		
Lichens	**Lichens**																																		
	# samples		10					2	1		2	3		10	14	2	5	2		6	1	1	6	2			1	1	2		5	6	4	5	
	Richness		11,80					18,00	5,00		54,00	31,00		33,60	28,79	33,50	23,20	6,50		9,67	31,00	31,00	21,67	30,00			54,00	53,00	19,00		33,40	33,67	13,25	25,00	
	Shannon (H)		2,11					2,68	1,61		3,93	3,41		3,44	3,22	2,59	2,59	1,85		1,44	3,42	2,17	2,33	3,40			3,98	3,92	2,93		3,41	2,36	2,21	3,15	
	Evenness E (H)		0,96					0,96	1,00		1,00	1,00		0,98	0,99	0,74	0,79	1,00		0,67	1,00	0,63	0,78	1,00			1,00	0,99	1,00		0,97	0,67	0,86	0,99	
	Simpson (D)		0,83					0,91	0,80		0,98	0,96		0,96	0,95	0,81	0,76	0,84		0,54	0,97	0,69	0,70	0,97			0,98	0,98	0,95		0,96	0,74	0,82	0,95	
	Evenness E (D)																																		
	Red List Species					0				0	12	1	12	4	8				9						0			4	1	5	1	1		2	2

		FSg	FSh	FSp	FSs		FWs		WCf	WCl	WCm	WSg	WSm	WSs	WLm	WLp	WLr	WLt	WRc	WRd	WRm	WRs		WGn		XFc	XFf	XFs	XFt	XFw		XMf	XMm	XMt		Total
Birds	Birds																																			
	#samples	19	14	7	2		17					5		3					2	1	12	5						9	1	2			1	2		
	Species richness	75	56	25	11		42					10		17		5			13	7	101	20						30	6	8			12	16		
	Shannon index	1,84332	1,73354	1,61229	1,32274		1,45232					1,16696		1,17506					1,47467	1,60944	2,49047	1,37305						1,3084	1,67699	1,53252			2,11844	1,70405		
	Evenness	0,88373	0,85569	0,95265	0,8858		0,88031					0,90316		0,85567					0,68841	1	0,82871	0,74489						0,84475	0,93594	0,96405			0,85252	0,91048		
	Simpson	6,67168	4,94652	4,90972	3,37582		4,35028					3,21971		2,86869					3,27119	5	11,4579	4,72578						3,70798	4,76471	4,45238			6,44025	5,67803		
	eveness	0,76814	0,63478	0,8481	0,73623		0,76					0,83709		0,70226					0,38304	1	0,50677	0,84974						0,74181	0,79412	0,89087			0,53669	0,73409		
	# Red List species	**2**	**1**			**2**		**0**				**1**				**1**			**1**		**6**		**9**		**0**						**0**			**1**	**1**	**12**
Mammals	Mammals																																			
	#samples																																			
	Species richness	6	2			6	2	2													4	2	6					3		2	3					
	Shannon index																																			
Herpetofauna	Herpetofauna																																			
	# samples																																			
	Richness	**1**	2			2	**1**	**1**	**2**			**2**					**1**		**1**	**2**	**1**	**1**	**4**	**2**	**1**	2		**3**	**1**	**3**	**4**					
	Shannon index (H)																																			
	Evenness E (H)																																			
	Simpsons Index (D)																																			
	Eveness E (D)																																			
	# Red List species																																			
	Insects																																			
Insects	Species																																			
	# samples	**24**	**24**	**1**	**14**		**13**					**3**	**5**	**1**										**5**				**1**	**1**	**7**		**2**		**2**		**191**
	Richness species	**70**	**43**	7	**32**		**41**					13	**28**	3										**26**				1	3	13		5		2		**197**
	Shannon (H)	3,79	3,41	1,61	3,23		3,28					2,06	2,82	0,92										2,61				0	0,69	2,53		1,61		0,54		
	Evenness E (H)	0,94	0,97	1	0,98		0,96					0,94	0,91	0,84										0,94				0	1	0,99		1		0,78		
	Simpson (D)	**34,25**	**26,63**	5	**22,94**		**22,13**					7,17	13,34	2,17										11,83				1	2	12,02		5		1,55		
	Evenness E (D)	0,60	0,78	1	0,85		0,71					0,80	0,61	0,72										0,74				1	1	0,92		1		0,78		
	# Red List species	**1**				**1**																														**2**
	Genus																																			
	# samples																																			
	Richness Genus	**16**	12	5	**10**		**10**					4	**11**	2										**10**				1	1	4		4		2		**31**
	Shannon (H)	1,95	1,99	1,42	2,01		1,58					0,69	1,21	0,69										1,49				0		1,24		1,18		0,64		
	Evenness E (H)	0,89	0,91	0,88	0,91		0,81					1	0,75	1										0,83				0		0,90		0,85		0,92		
	Simpson (D)	5,65	5,87	3,63	6,44		3,83					2	2,79	2										3,69				1		3,18		2,75		1,8		
	Evenness E (D)	0,63	0,65	0,73	0,72		0,55					1	0,56	1										0,61				1		0,79		0,69		0,9		
Fish	Fish																																			
	# samples										**1**						**5**	**3**	**8**		**47**	**2**														
	Richness										4						11	9	10		16	10														**24**
	Shannon (H)										1,14						1,70	1,07	1,37		2,36	0,13269														
	Evenness E (H)										0,82						0,71	0,49	0,60		0,87	0,19143														
	Simpson (D)										2,87						3,97	1,94	2,59		8,71	1,06055														
	Evenness E (D)										0,72						0,36	0,22	0,26		0,58	0,53028														
	Red List Species																2	2			**1**		**2**													**2**
Benthos	Benthos Families																																			
	# samples								2	3					13		15	13	15	9	129	66														
	Richness								9	8					18		**25**	18	17	14	**31**	**24**														**39**
	Shannon (H)								0,70707	1,70689					2,31		1,52	1,99	1,97	1,47	2,01	2,37														
	Evenness E (H)								0,3218	0,82084					0,80		0,47	0,69	0,70	0,56	0,59	0,75														
	Simpson (D)								1,41851	4,48823					7,89		2,80	5,82	5,91	3,51	4,31	6,32														
	Evenness E (D)								0,15761	0,56103					0,44		0,11	0,32	0,35	0,25	0,14	0,26														

Vegetation

		FSg	FSh	FSp	FSs		FWs		WCf	WCl	WCm	WSg	WSm	WSs	WLm	WLp	WLr	WLt	WRc	WRd	WRm	WRs		WGn		XFc	XFf	XFs	XFt	XFw		XMf	XMm	XMt		Total
Higher plants	Higher plants																																			
	# samples	30	19	1	22	72	19	20				12		2							4		18	16	16	3	1	1	15	12	32	8	1	2	11	
	Richness	22,17	41,63	25,00	23,41	27,72	40,84	40,15				30,58		36,00							6,25		25,78	41,94	41,9375	13,00	37,00	10,00	11,27	18,92	15,06	27,75	24,00	18,00	25,64	
	Max. spec.richness	48	56	25	48	56	64	64				58		43							8		58	64	64	17	37	10	26	39	39	41	24	20	41	
	Shannon (H)	1,81	2,42	1,97	1,92	2,01	2,26	2,27				2,10		2,52							0,70		1,84	2,72	2,72313	1,42	2,48	1,44	1,50	1,84	1,65	1,90	2,16	1,72	1,89	
	Evenness E (H)	0,60	0,65	0,61	0,62	0,62	0,61	0,62				0,64		0,71							0,42		0,60	0,73	0,73375	0,58	0,69	0,62	0,63	0,64	0,63	0,58	0,68	0,60	0,59	
	Simpson (D)	0,72	0,81	0,79	0,75	0,75	0,77	0,77				0,74		0,81							0,33		0,65	0,84	0,84438	0,61	0,88	0,58	0,67	0,75	0,70	0,74	0,83	0,74	0,75	
	Evenness E (D)																																			
	Red List Species	2	2			4	4	4				2											2	4	4		1		1	3	3	2	1	2	2	**7**
Mosses	Mosses																																			
	# samples	30	17	1	17		9					6		2							1			7		1	1	1	14	10		8	1	2		
	Richness	7,89	7,29	8,00	9,12		2,11					2,00		2,50							1,00			3,14		12,00	5,00	5,00	5,07	8,40		6,25	4,00	5,50		
	Shannon (H)	1,18	1,41	1,39	1,24		0,60					0,26		0,50							0,00			0,54		2,45	1,06	0,55	0,88	1,43		0,95	0,84	1,52		
	Evenness E (H)	0,58	0,75	0,67	0,57		0,68					0,29		0,49							0,00			0,49		0,99	0,66	0,34	0,62	0,71		0,52	0,60	0,89		
	Simpson (D)	0,55	0,65	0,66	0,54		0,39					0,15		0,31							0,00			0,31		0,91	0,54	0,24	0,45	0,65		0,44	0,48	0,74		
	Evenness E (D)																																			
	Red List Species																																			
Lichens	Lichens																																			
	# samples	19	16	1	15		12					1		1										5			1		5	8		8	1	2		
	Richness	39,35	33,63	40,00	37,67		24,25					9,00		1,00										20,40			13,00		11,80	18,50		39,88	53,00	26,00		
	Shannon (H)	3,64	3,49	3,69	3,59		3,14					2,20		0,00										2,58			2,56		2,34	2,86		3,67	3,91	2,61		
	Evenness E (H)	0,99	1,00	1,00	1,00		1,00					1,00		0,00										0,80			1,00		1,00	1,00		1,00	0,98	0,80		
	Simpson (D)	0,97	0,97	0,98	0,97		0,95					0,89		0,00										0,77			0,92		0,89	0,94		0,97	0,98	0,84		
	Evenness E (D)																																			
	Red List Species	10	9		11	15	9	9															0	8	8					3	3	7	4	1	9	**24**

Appendix 5 Disturbance class per relevee

Relevé number	Remarks	Site	Plotnr	Land_unit	Forest cut regime	Distur Bance class	Rich ness	Shannon	Evenness	Simpson	Richness/ average	Shannon/ average	Eveness/ average	Simpson/ average	Diversity Value	land unit
159	Komi Republic	Camp 4 Ust-Unja	2E+06	FAh	secondary	3	90	3,61	0,8	0,78	1,727119359	1,221408388	1,035414593	0,972328767	**4,96**	**FAh**
85	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FBg	40 years old	2	81	3,36	0,76	0,8	1,554407423	1,136823319	0,983643863	0,997260274	**4,67**	**FBg**
219	Sosnogorsky Region. Right bank of Velyu r	Camp 3 Synya	200284	FBg	tracks of fire	3	60	4,52	1,1	0,94	1,151412906	1,529298037	1,423695065	1,171780822	**5,28**	
116	Pechorsky Region	Camp 2 Jaksha	2E+06	FBg	tracks of fire	3	81	3,25	0,74	0,82	1,554407423	1,099605889	0,957758498	1,022191781	**4,63**	
66	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FBg	secondary	3	59	2,82	0,69	0,86	1,132222691	0,954119572	0,893045086	1,072054795	**4,05**	
67	Komi Republic	Camp 1 Velyu Komi	2E+06	FBg	secondary	3	53	2,72	0,69	0,79	1,0170814	0,920285544	0,893045086	0,984794521	**3,82**	
31	sur. of sity Pechora.	Camp 1 Pechora	200227	FBg	secondary	3	18	1,72	0,6	0,53	0,345423872	0,581945271	0,776560944	0,660684932	**2,36**	
96	Komi Republic	Camp 2 Jaksha	2E+07	FBg	logging area	4	53	2,94	0,74	0,81	1,0170814	0,994720405	0,957758498	1,009726027	**3,98**	
44	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FBg	selective cutting	4	55	2,67	0,67	0,87	1,05546183	0,903368531	0,867159721	1,084520548	**3,91**	
191	Sosnogorsky Region. Right bank of Velyu r	Camp 2 Synya	200260	FBh	secondary	3	96	4,62	1,01	0,97	1,84226065	1,563132064	1,307210923	1,209178082	**5,92**	**FBh**
158	Sosnogorsky Region. Right bank of Velyu r	Camp 4 Ust-Unja	2E+06	FBh	secondary	3	95	3,91	0,86	0,75	1,823070434	1,32291047	1,113070687	0,934931507	**5,19**	
77	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FBh	tracks of fire	3	79	3,14	0,72	0,9	1,516026993	1,062388459	0,931873133	1,121917808	**4,63**	
237	Troicko-Pechorsky Region	Camp 2 Synya	2E+07	FBh	tracks of fire	3	21	2,74	0,9	0,9	0,402994517	0,92705235	1,164841417	1,121917808	**3,62**	
84	Komi Republic	Camp 1 Velyu Komi	2E+06	FBl	40 years old	2	57	2,74	0,68	0,85	1,093842261	0,92705235	0,880102404	1,059589041	**3,96**	**FBl**
250	Pechora-Ilych R	Camp 3 ynya	2E+06	FBp	burnt 15 years ago	3	63	4,04	0,97	0,95	1,208983551	1,366894706	1,255440193	1,184246575	**5,02**	**FBp**
208	Komi Republic	Camp 2 Synya	200274	FBp	secondary	3	34	3,59	1,02	0,91	0,652467313	1,214641582	1,320153605	1,134383562	**4,32**	
95	sur. of sity Pechora.	Camp 2 Jaksha	2E+07	FBp	logging area	4	57	2,59	0,64	0,77	1,093842261	0,876301309	0,828331674	0,959863014	**3,76**	
182	Sosnogorsky Region. Right bank of Velyu r	Camp 2 Synya	200251	FBs	secondary	3	34	3,22	0,91	0,95	0,652467313	1,089455681	1,177784099	1,184246575	**4,10**	**FBs**
198	Komi Republic	Camp 2 Synya	200267	FBs	secondary	3	26	3,01	0,92	0,88	0,498945593	1,018404224	1,190726781	1,096986301	**3,81**	
214	Sosnogorsky Region. Territory of Turchani	Camp 3 Synya	200280	FDb	burnt area	4	67	3,94	0,94	0,97	1,285744412	1,333060678	1,216612146	1,209178082	**5,04**	**FDb**
238	neighbourhood o	Camp 3 Synya	2E+06	FDb	burnt area	4	40	3,33	0,9	0,94	0,767608604	1,126673111	1,164841417	1,171780822	**4,23**	
240	Troicko-Pechorsky Region	Camp 3 Synya	2E+06	FDb	burnt area	4	29	3,11	0,92	0,94	0,556516238	1,052238251	1,190726781	1,171780822	**3,97**	
235	neighbourhood o	Camp 3 Synya	2E+06	FDb	burnt area	4	17	2,57	0,91	0,88	0,326233657	0,869534503	1,177784099	1,096986301	**3,47**	
55	Komi Republic	Camp 1 Velyu Komi	2E+06	FDb	burned 5 years old	4	22	2,05	0,66	0,81	0,422184732	0,693597561	0,854217039	1,009726027	**2,98**	
54	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FDb	burned 5 years old	4	19	1,79	0,61	0,76	0,364614087	0,60562909	0,789503627	0,94739726	**2,71**	
45	Komi Republic	Camp 1 Velyu Komi	2E+06	FDg	selective cutting	4	56	2,9	0,72	0,77	1,074652046	0,981186794	0,931873133	0,959863014	**3,95**	**FDg**
41	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+07	FDl	clear cutting	4	48	2,35	0,61	0,8	0,921130325	0,795099643	0,789503627	0,997260274	**3,50**	**FDl**
181	Komi Republic	Camp 2 Synya	200250	FDm	12 years old	3	68	4,21	1	0,96	1,304934627	1,424412552	1,294268241	1,196712329	**5,22**	**FDm**
177	Komi Republic	Camp 2 Synya	200246	FDm	20 years old	3	33	3,36	0,96	0,93	0,633277098	1,136823319	1,242497511	1,159315068	**4,17**	
42	Komi Republic	Camp 1 Velyu Komi	2E+07	FDm	clear cutting	4	61	2,88	0,7	0,86	1,170603121	0,974419988	0,905987768	1,072054795	**4,12**	
109	Pechorsky Region	Camp 2 Jaksha	2E+06	FDm	logging area	4	60	2,92	0,71	0,81	1,151412906	0,987953599	0,918930451	1,009726027	**4,07**	
61	Komi Republic	Camp 1 Velyu Komi	2E+06	FDm	logging area	4	47	3,03	0,79	0,86	0,90194011	1,025171029	1,02247191	1,072054795	**4,02**	
173	Komi Republic	Camp 2 Synya	200242	FDs	10 years old	3	64	4,24	1,02	0,94	1,228173766	1,43456276	1,320153605	1,171780822	**5,15**	**FDs**
176	Sosnogorsky Region. Left bank of Velyu ri	Camp 2 Synya	200245	FDs	20 years old	3	59	3,96	0,97	0,95	1,132222691	1,339827484	1,255440193	1,184246575	**4,91**	
175	Komi Republic	Camp 2 Synya	200244	FDs	clearing area	4	14	2,39	0,91	0,89	0,268663011	0,808633254	1,177784099	1,109452055	**3,36**	
24	Pechorsky Region	Camp 1 Pechora	200220	FDs	young, after cutting	4	13	1,74	0,68	0,67	0,249472796	0,588712076	0,880102404	0,835205479	**2,55**	
107	sur. of sity Pechora.	Camp 2 Jaksha	2E+06	FMb	tracks of fire	3	93	3,53	0,78	0,74	1,784690004	1,194341166	1,009529228	0,922465753	**4,91**	**FMb**
145	Komi Republic	Camp 4 Ust-Unja	2E+06	FMp	50 years old	2	76	3,19	0,74	0,74	1,458456348	1,079305473	0,957758498	0,922465753	**4,42**	**FMp**
154	Sosnogorsky Region. Right bank of Velyu r	Camp 4 Ust-Unja	2E+06	FMs	10 years old	3	51	3,41	0,87	0,77	0,97870097	1,153740333	1,126013369	0,959863014	**4,22**	**FMs**
83	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FPg	40 years old	2	36	2,05	0,57	0,69	0,690847744	0,693597561	0,737732897	0,860136986	**2,98**	**FPg**
115	Komi Republic	Camp 2 Jaksha	2E+06	FPg	tracks of fire	3	73	3,3	0,77	0,77	1,400885702	1,116522903	0,996586545	0,959863014	**4,47**	
117	sur. of sity Pechora.	Camp 2 Jaksha	2E+06	FPg	tracks of fire	3	70	2,71	0,64	0,84	1,343315057	0,916902142	0,828331674	1,047123288	**4,14**	
104	Komi Republic	Camp 2 Jaksha	2E+06	FPg	tracks of fire	3	64	2,78	0,67	0,8	1,228173766	0,940585961	0,867159721	0,997260274	**4,03**	
16	sur. of sity Pechora.	Camp 1 Pechora	200212	FPg	secondary	3	10	1,37	0,6	0,51	0,191902151	0,463526175	0,776560944	0,635753425	**2,07**	
97	Pechorsky Region	Camp 2 Jaksha	2E+06	FPg	selective cutting	4	56	2,66	0,66	0,78	1,074652046	0,899985128	0,854217039	0,972328767	**3,80**	
34	sur. of sity Pechora.	Camp 1 Pechora	200230	FPg	selective cutting	4	13	1,35	0,52	0,61	0,249472796	0,456759369	0,673019485	0,760410959	**2,14**	
8	Pechorsky Region	Camp 1 Pechora	20026	FPg	selective cutting	4	8	1,19	0,57	0,43	0,153521721	0,402624926	0,737732897	0,536027397	**1,83**	
82	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FPl	40 years old	2	44	2,43	0,64	0,73	0,844369464	0,822166865	0,828331674	0,91	**3,40**	**FPl**
147	Komi Republic	Camp 4 Ust-Unja	2E+06	FPl	secondary	3	55	2,62	0,65	0,77	1,05546183	0,886451517	0,841274356	0,959863014	**3,74**	

Relevé number	Remarks	Site	Plotnr	Land_unit	Forest cut regime	Distur Bance class	Rich ness	Shannon	Evenness	Simpson	Richness/ average	Shannon/ average	Eveness/ average	Simpson/ average	Diversity Value	land unit
76	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FPl	tracks of fire	3	52	2,7	0,68	0,76	0,997891185	0,913518739	0,880102404	0,94739726	**3,74**	
103	sur. of sity Pechora.	Camp 2 Jaksha	2E+06	FPl	tracks of fire	3	56	2,59	0,64	0,74	1,074652046	0,876301309	0,828331674	0,922465753	**3,70**	
102	Pechorsky Region	Camp 2 Jaksha	2E+06	FPl	tracks of fire	3	34	2,08	0,59	0,69	0,652467313	0,703747769	0,763618262	0,860136986	**2,98**	
33	Pechorsky Region	Camp 1 Pechora	200229	FPl	tracks of fire	3	7	0,92	0,47	0,35	0,134331506	0,311273052	0,608306073	0,43630137	**1,49**	
9	sur. of sity Pechora.	Camp 1 Pechora	20027	FPl	young, after cutting	4	8	1,27	0,61	0,65	0,153521721	0,429692148	0,789503627	0,810273973	**2,18**	
215	Komi Republic	Camp 32 Synya	200281	FPp	tracks of fire	3	31	3,27	0,95	0,92	0,594896668	1,106372695	1,229554829	1,146849315	**4,08**	**FPp**
216	Sosnogorsky Region. Right bank of Velyu r	Camp 2 Synya	200282	FPp	tracks of fire	3	25	2,86	0,89	0,92	0,479755377	0,967653183	1,151898734	1,146849315	**3,75**	
234	Troicko-Pechorsky Region	Camp 3 Synya	200299	FPp	tracks of fire	3	23	2,83	0,9	0,91	0,441374947	0,957502974	1,164841417	1,134383562	**3,70**	
25	sur. of sity Pechora.	Camp 1 Pechora	200221	FPs	45 years old	2	12	2,02	0,81	0,67	0,230282581	0,683447353	1,048357275	0,835205479	**2,80**	**FPs**
114	sur. of sity Pechora.	Camp 2 Jaksha	2E+06	FPs	tracks of fire	3	60	3,21	0,78	0,79	1,151412906	1,086072278	1,009529228	0,984794521	**4,23**	
56	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FPs	tracks of fire	3	38	2,55	0,7	0,83	0,729228174	0,862767698	0,905987768	1,034657534	**3,53**	
62	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FPs	selective cutting	4	47	2,56	0,67	0,81	0,90194011	0,866151101	0,867159721	1,009726027	**3,64**	
251	Komi Republic	Camp 3 Synya	2E+06	FSg	undisturbed	1	66	4,26	1,02	0,93	1,266554197	1,441329566	1,320153605	1,159315068	**5,19**	**FSg**
46	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FSg	undisturbed	1	76	3,13	0,72	0,8	1,458456348	1,059005057	0,931873133	0,997260274	**4,45**	
80	Komi Republic	Camp 1 Velyu Komi	2E+06	FSg	undisturbed	1	68	3,07	0,73	0,79	1,304934627	1,03870464	0,944815816	0,984794521	**4,27**	
60	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FSg	undisturbed	1	68	2,9	0,69	0,8	1,304934627	0,981186794	0,893045086	0,997260274	**4,18**	
27	Pechorsky Region	Camp 1 Pechora	200223	FSg	undisturbed	1	12	1,54	0,62	0,62	0,230282581	0,521044021	0,802446309	0,772876712	**2,33**	
184	Sosnogorsky Region. Right bank of Velyu r	Camp 2 Synya	200253	FSg	40 years old	2	71	4,22	0,99	0,96	1,362505272	1,427795955	1,281325558	1,196712329	**5,27**	
144	Sosnogorsky Region. Right bank of Velyu r	Camp 4 Ust-Unja	2E+07	FSg	50 years old	2	67	2,86	0,68	0,8	1,285744412	0,967653183	0,880102404	0,997260274	**4,13**	
43	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FSg	40 years old	2	61	2,91	0,71	0,78	1,170603121	0,984570196	0,918930451	0,972328767	**4,05**	
180	Sosnogorsky Region. Left bank of Velyu ri	Camp 2 Synya	200249	FSg	secondary	3	52	3,79	0,96	0,95	0,997891185	1,282309637	1,242497511	1,184246575	**4,71**	
143	Komi Republic	Camp 4 Ust-Unja	2E+07	FSg	selective cutting	4	97	3,89	0,85	0,8	1,861450865	1,316143664	1,100128005	0,997260274	**5,27**	
68	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FSg	selective cutting	4	74	3,09	0,72	0,79	1,420075917	1,045471446	0,931873133	0,984794521	**4,38**	
40	Pechorsky Region	Camp 1 Velyu Komi	2E+06	FSg	selective cutting	4	61	3,19	0,77	0,76	1,170603121	1,079305473	0,996586545	0,94739726	**4,19**	
90	Komi Republic	Camp 1 Velyu Komi	2E+06	FSg	selective cutting	4	65	2,96	0,71	0,8	1,247363981	1,00148721	0,918930451	0,997260274	**4,17**	
148	Sosnogorsky Region. Right bank of Velyu r	Camp 4 Ust-Unja	2E+06	FSg	selective cutting	4	68	2,87	0,68	0,75	1,304934627	0,971036585	0,880102404	0,934931507	**4,09**	
10	Komi Republic	Camp 1 Pechora	20028	FSg	tracks of cutting and fire	4	31	2,17	0,63	0,69	0,594896668	0,734198394	0,815388992	0,860136986	**3,00**	
37	sur. of sity Pechora.	Camp 1 Pechora	200233	FSg	selective cutting	4	25	2,23	0,69	0,68	0,479755377	0,75449881	0,893045086	0,847671233	**2,97**	
11	Pechorsky Region	Camp 1 Pechora	20028	FSg	tracks of cutting and fire	4	32	2,12	0,61	0,64	0,614086883	0,71728138	0,789503627	0,797808219	**2,92**	
15	Pechorsky Region	Camp 1 Pechora	200211	FSg	selective cutting	4	19	1,69	0,58	0,59	0,364614087	0,571795062	0,75067558	0,735479452	**2,42**	
183	Komi Republic	Camp 2 Synya	200252	FSh	undisturbed	1	92	4,39	0,97	0,97	1,765499789	1,485313801	1,255440193	1,209178082	**5,72**	**FSh**
232	Komi Republic	Camp 3 Synya	200297	FSh	undisturbed	1	77	4,41	1,02	0,96	1,477646563	1,492080607	1,320153605	1,196712329	**5,49**	
246	Troicko-Pechorsky Region	Camp 2 Synya	2E+06	FSh	undisturbed	1	76	4,34	1	0,97	1,458456348	1,468396788	1,294268241	1,209178082	**5,43**	
239	Komi Republic	Camp 3 Synya	2E+06	FSh	undisturbed	1	41	3,59	0,97	0,93	0,786798819	1,214641582	1,255440193	1,159315068	**4,42**	
213	Komi Republic	Camp 32 Synya	200279	FSh	tracks of fire	3	99	4,52	0,98	0,97	1,899831295	1,529298037	1,268382876	1,209178082	**5,91**	
89	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FSh	selective cutting	4	86	3,36	0,75	0,84	1,650358499	1,136823319	0,97070118	1,047123288	**4,81**	
112	Pechorsky Region	Camp 2 Jaksha	2E+06	FSs	undisturbed	1	109	3,77	0,8	0,86	2,091733446	1,275542832	1,035414593	1,072054795	**5,47**	**FSs**
146	Sosnogorsky Region. Right bank of Velyu r	Camp 4 Ust-Unja	2E+06	FSs	undisturbed	1	111	3,52	0,75	0,86	2,130113876	1,190957763	0,97070118	1,072054795	**5,36**	
202	Komi Republic	Camp 2 Synya	200271	FSs	undisturbed	1	57	4,09	1,01	0,92	1,093842261	1,383811719	1,307210923	1,146849315	**4,93**	
69	sur. of sity Pechora.	Camp 1 Velyu Komi	2E+06	FSs	undisturbed	1	62	2,75	0,67	0,78	1,189793336	0,930435753	0,867159721	0,972328767	**3,96**	
14	Komi Republic	Camp 1 Pechora	200210	FSs	100 years old	2	21	1,83	0,6	0,39	0,402994517	0,619162701	0,776560944	0,486164384	**2,28**	
13	sur. of sity Pechora.	Camp 1 Pechora	200210	FSs	secondary	3	27	2,07	0,63	0,63	0,518135808	0,700364366	0,815388992	0,785342466	**2,82**	
						Average:	52,1	2,9556	0,773	0,8022					185 in total, 91 have information on disturbance	

Appendix 6 Diversity per MODIS class

Birds							
Modis class		**Richness species**	**Shannon (H)**	**Evenness E (H)**	**Simpson (D)**	**Evenness E (D)**	**Red List species**
1	Pine forest (> 70 %) (100)	39,00	1,84	0,93	6,15	0,78	1
2	Spruce/dark coniferous forest (> 70 %) (200)	41,75	1,63	0,89	4,98	0,75	1,5
3	Meadows/willow shrub (500)	19,75	1,28	0,88	3,71	0,76	1
4	Mixed forest, pine dominated (610)	53,00	1,96	0,94	6,88	0,79	0
5	Mixed forest, spruce dominated (620)	56,00	2,00	0,93	7,27	0,79	2
6	Mixed forest, birch dominated (640)	19,57	2,04	0,91	6,90	0,70	0
7	Disturbed forest, clearcut/regrowth (710)	12,75	1,67	0,84	5,05	0,60	0
8	Unclassified pine/bush fire (750)	18,00	1,59	0,98	5,09	0,92	0
10	Mountain tundra (830)	16,00	1,70	0,91	5,68	0,73	1
11	Mountains, Open forest (850)	12,00	2,12	0,85	6,44	0,54	0
17	Rich fen, Carex (910)	0,00	0,00	0,00	0,00	0,00	0
18	Poor fen, raised bog (930)	18,00	1,49	0,89	4,24	0,77	0
19	Poor fen, partly wooded with pine (950)	8,00	1,53	0,96	4,45	0,89	0
20	Sandbank, bare soil, dunes (1050)	13,50	1,17	0,88	3,04	0,77	1
21	Water (1070)	29,20	1,74	0,82	6,11	0,68	2,25
22	Coastal meadows (1017)	0,00	0,00	0,00	0,00	0,00	0
no modis		30,67	1,67	0,78	6,06	0,69	2

Insects, spec.							
Modis class		**Richness species**	**Shannon (H)**	**Evenness E (H)**	**Simpson (D)**	**Evenness E (D)**	**Red List species**
1	Pine forest (> 70 %) (100)	11,25	1,79	0,86	6,95	0,76	0
2	Spruce/dark coniferous forest (> 70 %) (200)	31,40	2,73	0,98	18,76	0,85	1
3	Meadows/willow shrub (500)	25,00	2,65	0,93	13,26	0,70	0
4	Mixed forest, pine dominated (610)	7,00	1,81	0,93	5,62	0,80	0
5	Mixed forest, spruce dominated (620)	14,00	2,24	0,94	8,38	0,76	0
6	Mixed forest, birch dominated (640)	18,14	2,42	0,93	10,71	0,71	1
7	Disturbed forest, clearcut/regrowth (710)	10,25	1,47	0,69	6,69	0,82	0
8	Unclassified pine/bush fire (750)	3,00	0,92	0,84	2,17	0,72	0
10	Mountain tundra (830)	2,00	0,54	0,78	1,55	0,78	0
11	Mountains, Open forest (850)	0,00	0,00	0,00	0,00	0,00	0
17	Rich fen, Carex (910)	0,00	0,00	0,00	0,00	0,00	0
18	Poor fen, raised bog (930)	2,00	0,35	0,50	1,50	1,00	0
19	Poor fen, partly wooded with pine (950)	13,00	2,53	0,99	12,02	0,92	0
20	Sandbank, bare soil, dunes (1050)	8,00	1,49	0,89	4,67	0,76	0
21	Water (1070)	0,00	0,00	0,00	0,00	0,00	0
22	Coastal meadows (1017)	28,00	2,82	0,91	13,34	0,61	0
no modis		5,33	0	0	1	1	0

Insects, genus

Modis class		Richness species	Shannon (H)	Evenness E (H)	Simpson (D)	Evenness E (D)	Red List species
1	Pine forest (> 70 %) (100)	7,00	1,15	0,61	2,65	0,41	
2	Spruce/dark coniferous forest (> 70 %) (200)	9,40	1,71	0,89	4,87	0,68	
3	Meadows/willow shrub (500)	8,60	1,41	0,81	3,54	0,61	
4	Mixed forest, pine dominated (610)	6,00	1,47	0,82	3,31	0,55	
5	Mixed forest, spruce dominated (620)	10,00	1,95	0,94	6,12	0,77	
6	Mixed forest, birch dominated (640)	6,43	1,36	0,81	3,26	0,61	
7	Disturbed forest, clearcut/regrowth (710)	3,75	1,08	0,72	2,94	0,61	
8	Unclassified pine/bush fire (750)	5,00	1,39	0,86	3,60	0,72	
10	Mountain tundra (830)	2,00	0,64	0,92	1,80	0,90	
11	Mountains, Open forest (850)	0,00	0,00	0,00	0,00	0,00	
17	Rich fen, Carex (910)	0,00	0,00	0,00	0,00	0,00	
18	Poor fen, raised bog (930)	1,00	0,00	0,00	1,00	1,00	
19	Poor fen, partly wooded with pine (950)	4,00	1,24	0,90	3,18	0,79	
20	Sandbank, bare soil, dunes (1050)	3,00	0,69	1,00	2,00	1,00	
21	Water (1070)	0,00	0,00	0,00	0,00	0,00	
22	Coastal meadows (1017)	11,00	1,21	0,75	2,79	0,56	
no modis		3,33	0,65	0,59	1,56	0,52	

Fish

Modis class		Richness species	Shannon (H)	Evenness E (H)	Simpson (D)	Evenness E (D)	Red List species
1	Pine forest (> 70 %) (100)	0	0	0	0	0	0
2	Spruce/dark coniferous forest (> 70 %) (200)	0	0	0	0	0	0
3	Meadows/willow shrub (500)	0	0	0	0	0	0
4	Mixed forest, pine dominated (610)	0	0	0	0	0	0
5	Mixed forest, spruce dominated (620)	0	0	0	0	0	0
6	Mixed forest, birch dominated (640)	0	0	0	0	0	0
7	Disturbed forest, clearcut/regrowth (710)	0	0	0	0	0	0
8	Unclassified pine/bush fire (750)	0	0	0	0	0	0
10	Mountain tundra (830)	0	0	0	0	0	0
11	Mountains, Open forest (850)	0	0	0	0	0	0
17	Rich fen, Carex (910)	0	0	0	0	0	0
18	Poor fen, raised bog (930)	0	0	0	0	0	0
19	Poor fen, partly wooded with pine (950)	0	0	0	0	0	0
20	Sandbank, bare soil, dunes (1050)	0	0	0	0	0	0
21	Water (1070)	10	1,29	0,61	3,52	0,44	1
22	Coastal meadows (1017)	0	0	0	0	0	0
no modis		0	0	0	0	0	0

Benthos Families

Modis class		Richness species	Shannon (H)	Evenness E (H)	Simpson (D)	Evenness E (D)	Red List species
1	Pine forest (> 70 %) (100)	0	0	0	0	0	
2	Spruce/dark coniferous forest (> 70 %) (200)	0	0	0	0	0	
3	Meadows/willow shrub (500)	0	0	0	0	0	
4	Mixed forest, pine dominated (610)	0	0	0	0	0	
5	Mixed forest, spruce dominated (620)	0	0	0	0	0	
6	Mixed forest, birch dominated (640)	0	0	0	0	0	
7	Disturbed forest, clearcut/regrowth (710)	0	0	0	0	0	
8	Unclassified pine/bush fire (750)	0	0	0	0	0	
10	Mountain tundra (830)	0	0	0	0	0	
11	Mountains, Open forest (850)	0	0	0	0	0	
17	Rich fen, Carex (910)	0	0	0	0	0	
18	Poor fen, raised bog (930)	0	0	0	0	0	
19	Poor fen, partly wooded with pine (950)	0	0	0	0	0	
20	Sandbank, bare soil, dunes (1050)	0	0	0	0	0	
21	Water (1070)	18,22	1,78	0,63	4,72	0,29	
22	Coastal meadows (1017)	0	0	0	0	0	
no modis		0	0	0	0	0	

Higher plants

Modis class		Richness species	Shannon (H)	Evenness E (H)	Simpson (D)	Evenness E (D)	Red List species
1	Pine forest (> 70 %) (100)	13,23	1,37	0,54	0,62	0	1,33
2	Spruce/dark coniferous forest (> 70 %) (200)	27,99	2,00	0,61	0,76	0	2
3	Meadows/willow shrub (500)	42,75	2,85	0,76	0,85	0	2,5
4	Mixed forest, pine dominated (610)	17,00	1,55	0,55	0,71	0	1
5	Mixed forest, spruce dominated (620)	30,00	2,14	0,64	0,82	0	1
6	Mixed forest, birch dominated (640)	29,20	2,04	0,62	0,78	0	2,5
7	Disturbed forest, clearcut/regrowth (710)	16,07	1,57	0,57	0,69	0	0
8	Unclassified pine/bush fire (750)	18,00	1,71	0,60	0,72	0	0
10	Mountain tundra (830)	18,00	1,72	0,60	0,74	0	2
11	Mountains, Open forest (850)	24,00	2,16	0,68	0,83	0	1
17	Rich fen, Carex (910)	25,00	1,95	0,63	0,74	0	1
18	Poor fen, raised bog (930)	10,63	1,47	0,62	0,63	0	1
19	Poor fen, partly wooded with pine (950)	18,92	1,84	0,64	0,75	0	3
20	Sandbank, bare soil, dunes (1050)	33,29	2,31	0,67	0,77	0	2
21	Water (1070)	6,25	0,70	0,42	0,33	0	0
22	Coastal meadows (1017)	0,00	0,00	0,00	0,00	0	0
no modis		26,88	2,09	0,65	0,74	0	1

Mosses

Modis class		**Richness species**	**Shannon (H)**	**Evenness E (H)**	**Simpson (D)**	**Evenness E (D)**	**Red List species**
1	Pine forest (> 70 %) (100)	4,91	0,88	0,53	0,43	0	0
2	Spruce/dark coniferous forest (> 70 %) (200)	7,71	1,23	0,62	0,57	0	0
3	Meadows/willow shrub (500)	2,56	0,61	0,64	0,39	0	0
4	Mixed forest, pine dominated (610)	6	0,51	0,28	0,2	0	0
5	Mixed forest, spruce dominated (620)	8	1,2	0,57	0,54	0	0
6	Mixed forest, birch dominated (640)	6,62	1,00	0,54	0,46	0	0
7	Disturbed forest, clearcut/regrowth (710)	8,13	1,32	0,66	0,60	0	0
8	Unclassified pine/bush fire (750)	4,67	0,54	0,36	0,24	0	0
10	Mountain tundra (830)	5,5	1,52	0,89	0,74	0	0
11	Mountains, Open forest (850)	4	0,84	0,6	0,48	0	0
17	Rich fen, Carex (910)	8,50	1,76	0,83	0,73	0	0
18	Poor fen, raised bog (930)	5,04	0,72	0,48	0,35	0	0
19	Poor fen, partly wooded with pine (950)	8,40	1,43	0,71	0,65	0	0
20	Sandbank, bare soil, dunes (1050)	2,25	0,38	0,39	0,23	0	0
21	Water (1070)	1	0	0	0	0	0
22	Coastal meadows (1017)	0	0	0	0	0	0
no modis		2,83	0,37	0,23	0,19	0	0