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Application of the Red List Index as an indicator of habitat change

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Abstract

For the first time ever, the International Union for Conservation of Nature Red List Index for habitat types was calculated for an entire country, Finland. The RLIs were based on species threat assessments from 2000 and 2010 and included habitat definitions for all 10 131 species of 12 organism groups. The RLIs were bootstrapped to track statistically significant changes. The RLI changes of species grouped by habitats were negative for all habitat types except for forests and rural biotopes which showed a stable trend. Trends of beetles and true bugs were positive in rural and forest habitats. Other 16 observed trends of species group and habitat combinations were negative. Several trends observed were in accordance with studies focusing on particular taxa and habitats, and drivers for their change. This study demonstrates the usefulness of the RLI as a tool for observing habitat change based on species threat assessment data.

Keywords: biodiversity indicator, biodiversity loss, habitat, Finland, RLI, threatened species

1. Introduction

The 2010 conference of the parties to the Convention on Biological Diversity (CBD) in Aichi, Japan declared the 2010–2020 decade as a Decade on Biodiversity. Twenty biodiversity targets were set to be met by the year 2020 (Tittensor et al. 2014). Among these, target 12 says "By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained". The IUCN Red List of Threatened Species is the most widely used information source on the extinction risk of species (Rodrigues et al. 2006; Mace et al. 2008; but see Cardoso et al. 2011, 2012). The IUCN Red List Index (RLI) (Butchart et al. 2004, 2007), which reflects overall changes in IUCN Red List status over time of a group of taxa, was agreed by the parties to the CBD to be used as an overall index of change, to quantify to what extent target 12 is being met.

The RLI uses weight scores based on the Red List status of each of the assessed species. These scores range from 0 (Least Concern) to Extinct/Extinct in the Wild (5). Summing these scores across all species and relating them to the worst-case scenario - all species extinct - gives us an indication of how biodiversity is doing. Importantly, the RLI is based on true improvements or deteriorations in the status of species, i.e. "genuine changes". It excludes category changes resulting from, e.g., new knowledge (Butchart et al. 2007).The RLI approach helps to develop a better understanding of which taxa, regions or ecosystems are declining or improving. The aim is to provide policy makers, stakeholders, conservation practitioners and the general public with sound knowledge of biodiversity status and change, and tools with which to make informed decisions.

At a global level, the IUCN Red List Index has been calculated for birds (Butchart et al. 2004; Hoffman et al. 2010), mammals (Hoffmann et al. 2010, 2011), amphibians (Hoffman et al. 2010), corals (Butchart et al. 2010), and cycads (The Millenium Development Goals Report 2015). An ongoing project is heading to present a sampled Red List Index (SRLI, Baillie et al. 2008) of plants (Brummitt et al. 2015) and efforts towards a SRLI of butterflies (Lewis and Senior 2011) and Odonata are made (Clausnitzer et al. 2009). At a regional and national level, RLIs or SRLIs have been presented for certain groups (Lopez et al. 2011; Szabo et al. 2012; Moreno Saiz et al. 2015; Woinarski et al. 2015) or multiple species groups (Gärdenfors 2010; Juslén et al. 2013; Rondinini et al. 2014).

A parallel set of criteria was proposed to be applied to ecosystems in lieu of species, with much the same objectives, the IUCN Red List of Ecosystems (RLE, Rodríguez et al. 2011). This has not been widely adopted as of yet, either at global or regional scales. National assessments of threatened habitat types have been carried out, for example in Finland (Raunio et al. 2008; Kontula and Raunio 2009). Kontula and Raunio (2009) even presented a procedure for assigning IUCN Red List categories for habitat types. However, this assessment has been carried out only once in Finland, and temporal trends cannot be presented as of yet.Until repeated assessments of risk of collapse of particular ecosystem types are available using the Red List of Ecosystems approach, it will not be possible to produce a Red List Index for different ecosystems using the RLE approach. However, as a proxy for ecosystem or habitat change, it is possible to calculate RLIs for sets of species characteristic of particular ecosystem or habitat types. Butchart et al. (2004) has already used such an approach for birds. In practice, any index based on species trends that includes additional information such as habitat types can be used to perceive trends on species groups other than taxonomic. Besides the RLI, we can mention the Living Planet Index (LPI), which is based on population trends of vertebrates from around the world and that has been used in multiple ways, including for quantifying habitat trends (Loh et al. 2005; Collen et al. 2009). The LPI does however require much more information than the RLI, hence its focus on vertebrates.

Here we propose and develop the first national RLI applied to ecosystem level, using Finnish species and their habitats as an example. The approach is intended to complement both the taxon-based RLI and the ecosystem-based RLE, bridging the gap between the two.

2. Material and methods

2.1 Species data

There are approximately 45 000 known species in Finland, and about 21 400 of these had adequate data for threat assessments both in 2000 and 2010 (Rassi et al. 2001, 2010). The present study is based on 10 131 taxa assessed in both years, (Table 1), as we restricted the analyses to species groups well covered in both assessments: beetles (3 384 species), butterflies & moths (below denoted as butterflies) (2 247), lichens (1 392), vascular plants (1 197), bryophytes (873), true bugs (463), birds (237), polypores (220), mammals (57), dragonflies and damselflies (51) and herptiles (10).

As a part of the method, back casting was used to identify the species with genuine threat category changes. The 2000 Red List categories were adjusted retrospectively based on current information and taxonomy when needed. The RLI calculations include only category changes due to genuine changes in species statuses (Butchart et al. 2007). Back casting was performed already for species groups other than Lepidoptera by Juslén et al. (2013). The reasons for any category change are listed in Rassi et al. 2010 for the species in threatened categories regionally extinct (RE), critically endangered (CR), endangered (EN), vulnerable (VU), near-threatened (NT) and data deficient (DD). The working documentation lists reasons for the Least Concern (LC) species. Any challenging back casting cases were separately discussed with experts of the group in question. Regarding Lepidoptera, LK and JK have made the back casting purposely for the study now presented. Altogether 529 genuine changes were found in the 12 groups studied (Table 1).

2.2. Habitat data

The habitats for species listed in the Finnish Red Data Book (i.e. for those categorized as RE, CR, EN, VU, and NT) were published by Rassi et al. (2010). For LC species we followed the unpublished habitat classification listed at the threat assessment documentation or other working documentation produced by expert groups during two years (except beetles and butterflies, for which no classification was produced previously).

The habitat classification categories were: forests, mires, aquatic habitats, shores, rock outcrops (including erratic boulders), alpine heaths and meadows above tree-level, and rural biotopes and cultural habitats. Definitions of the habitats are given in table 2, and more detailed subcategorizations are published in Rassi et al. 2010. These differ from the standard classifications by IUCN (http://www.iucnredlist.org/technical-documents/classification-schemes/habitats-classification-scheme-ver3) in two ways (see also Tables 2 and 5). First, mires were separated from other aquatic habitats due to their exceptional extension in Finland and importance for many Finnish species. Second, marine intertidal and coastal areas were merged due to the difficulty in separating them given the characteristics of Finnish geology and marine hydrology.

The habitat classification for Least Concern beetles and butterflies was conducted in this study. Habitats of the Least Concern species of Coleoptera were based on published sources (Koch 1989a, 1989b, 1992) and checked by Jaakko Mattila and Jyrki Muona. Besides own expertise, we used a database consisting of 670 000 observations of beetles in Finland. This database is not public, but the Finnish Coleoptera Atlas based on the database has been published (The Finnish Expert Group on Coleoptera 2010). The habitats of the least concern species of Lepidoptera were defined by experts Lauri Kaila and Jaakko Kullberg, who also had a database of Lepidoptera of 1.600 000 observations supporting their work (Hyönteistietokanta).

Additionally, a few missing habitats for the other ten groups of organisms were obtained with the help of the Finnish expert groups of species. The whole habitat classification data per species is given in Appendix 1.

Often species occur and establish sustaining populations on several habitat types. Yet, one habitat could always be pointed out by experts as the primary habitat type. This might be the original habitat of the species, for instance, *Thymus serpyllum* is classified to forests, as its original main habitat in Finland is esker forests (Hämet-Ahti et al. 1998), although it nowadays also occurs on sandy riverbanks and sometimes on sandy road banks. Or it might be the habitat where the species occurs in higher abundance. For high-mobility animals, that may occur in different habitats seasonally or during their life cycles, e.g. birds, the primary habitat was the preferential nesting habitat. Habitats of holomethabolic insects were defined according to the larvae preference, as most of their life-cycle is spent on this stage.

2.3. The Red List Index for habitats

Based on the red-list status of species occupying each habitat, we calculated the RLI for habitats.

The RLI value was calculated by multiplying the number of taxa in each red-list category by the category weight (0 for LC, 1 for NT, 2 for VU, 3 for EN, 4 for CR, 5 for RE/EX). These products were summed and then divided by the number of taxa multiplied by the maximum weight 5 (“maximum possible denominator”). To obtain the RLI value, this sum is subtracted from 1. The index value varies between 0 and 1 (Butchart et al. 2007). The lower the value, the closer the set of taxa is heading towards extinction. If the value is 0 all the taxa are (regionally) extinct. If the value is 1 all the taxa are assessed as Least Concern. The instructions for national and regional use by Bubb et al. (2009) exclude the species that have been assessed as Extinct (EX) in the earlier assessment. We calculated the RLIs including the taxa assessed as Regionally Extinct (RE) in 2000, as some of these taxa were rediscovered in Finland during the observed period (see also Juslén et al. 2013).

2.4. Statistical analysis

We conducted independent analyses with different species groupings by taxon, by habitat and a combination of these. For each group of species in the three groupings we calculated three values: RLI 2000, RLI 2010 and the change between the years (i.e. RLI 2010 – RLI 2000). A simple arithmetic analysis would not show whether the group indices were statistically different or the change between the years was significantly different from a null hypothesis of no change. We therefore resampled all the values with non-parametric bootstrapping. For each group, species were randomly sampled with replacement until the original number of species was attained. For each of the 10.000 resampling events the RLI 2000, RLI 2010 and the respective differences were calculated. The confidence limits ($\alpha = 0.05$) of the RLI values per group and year were the 2.5 and 97.5 percentiles of the respective 10.000 randomizations. The change between the years was considered statistically significant if more than 95% of the randomization values had the same sign (either increase or decrease) as the true values. Statistics were performed using the R 3.1.2 statistical environment (R Core Team 2014).

3. Results

The number of taxa in different primary habitats was 4 031 in forests, 513 in mires, 633 in aquatic habitats, 1 257 in shores, 969 in rock outcrops, 411 in alpine heaths and meadows, and 2 317 in rural biotopes (Table 3).

The RLI value for all Finnish species combined was 0.882 in 2000 and 0.879 in 2010. The minor changes observed against Juslén et al. (2013) were due to the inclusion of Lepidoptera in the dataset. The new bootstrap analyses showed that dragonflies, true bugs and beetles were statistically less threatened than the other groups, whose confidence limits mostly overlap (Fig. 1). The RLI changes between the years were significantly negative for bryophytes, lichens, vascular plants, butterflies and birds and positive for beetles and true bugs (Table 4). Dragonflies, herptiles, mammals and polypores show no significant trend.

Alpine habitats followed by rock outcrops present the most threatened species on average, with aquatic habitats, forests and mires hosting the least threatened (Fig. 2). The RLI changes between the years were significantly negative for all habitat types except forests and rural biotopes, which show no significant trends (Table 5).

Significant RLI trends between 2000 and 2010 were found for 20 combinations of groups of organisms with primary habitats (Table 6; Appendix 2). The trends of beetles and true bugs were positive in rural and forest habitats, otherwise observed trends were all negative. Trends of bryophytes were negative in six habitats and of vascular plants in five. Negative trends were also recovered in two habitats for both birds and lichens, and in one habitat for butterflies. In dragonflies and damselflies, polypores, herptiles and mammals no positive or negative trends were observed (Appendix 2).

4. Discussion

This study demonstrates that it is useful to calculate the RLI for species grouped by habitat, in addition to the usual taxonomic grouping. Several trends were revealed in accordance with published studies focusing on particular taxa and habitats. In general, more negative trends were found, with positive trends being possibly due to the effects of climate warming on several insect species that are expanding northwards. Few scientific papers analyzing reasons for population changes among the Finnish threatened species other than birds exist. Only in one habitat type (forests) several papers focused on recent trends in threatened species were available, such as the simulation study by Fedrowitz et al. (2012) showing continuous decrease of threatened epiphytic lichens. Our main findings, grouped by habitats, are elaborated in the table 5 with likely drivers and references with supporting notes.

We suggest that the habitat-based RLI may show a different, complementary view to the ecosystem-based RLE. Even though some habitats may not be improving, their constituent species may show positive trends due to other factors such as the climate change. The habitat-based RLI clearly bridges the gap between the taxon-based RLI and the RLE.

The RLI has been used in multiple ways, usually to evaluate the impact of contrasting policies on the threat status of different taxonomic groups. Hoffmann et al. (2011) used it to attempt to quantify the impact of conservation efforts on the extinction risk of two groups of mammals. Young et al. (2014) quantified the impact of a conservation organisation´s programmes on extinction risk of a set of species. Visconti et al. (2015) used the RLI for projecting the likely impact of different policy decisions. Moreno Saiz et al. (2015) tested it as a tool to assess the success of national conservation policies.

The latter authors recommended using various indicators as basis for planning regional conservation measures and evaluating their success. However, they also listed several challenges in using and interpreting the RLI. Above all, they recognize it is a summary statistic, which may mask the individual patterns under a global trend. For example, if 10 species increase and 10 decrease in their status the index will reveal the exact same value as if no species change at all, although these are quite different situations. Researchers and stakeholders should therefore always search for individual species that may be at odds with the general trend of the group and try to understand why this might happen. Although this is also verified in the present study, our results show the RLI to be useful for evaluating species trends in different habitat types.

As mentioned, besides the RLI other indices can be disaggregated into different groups so that different aspects of biodiversity change can be studied. These might be taxonomic groups (the subject of most RLI studies), habitat types (the subject of this study), or many other. Dividing species into functional groups may be a particularly useful way of using the RLI, as function is related with ecosystem services and thus trends in particular groups may reveal or even precede changes in services, many of them critical for human well-being.

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Figure captions

Figure 1. The RLI trends between 2000 and 2010 showing the confidence limits for RLI values of each group of organisms.

Figure 2. The RLI trends between 2000 and 2010 showing the confidence limits for RLI values of each primary habitat.

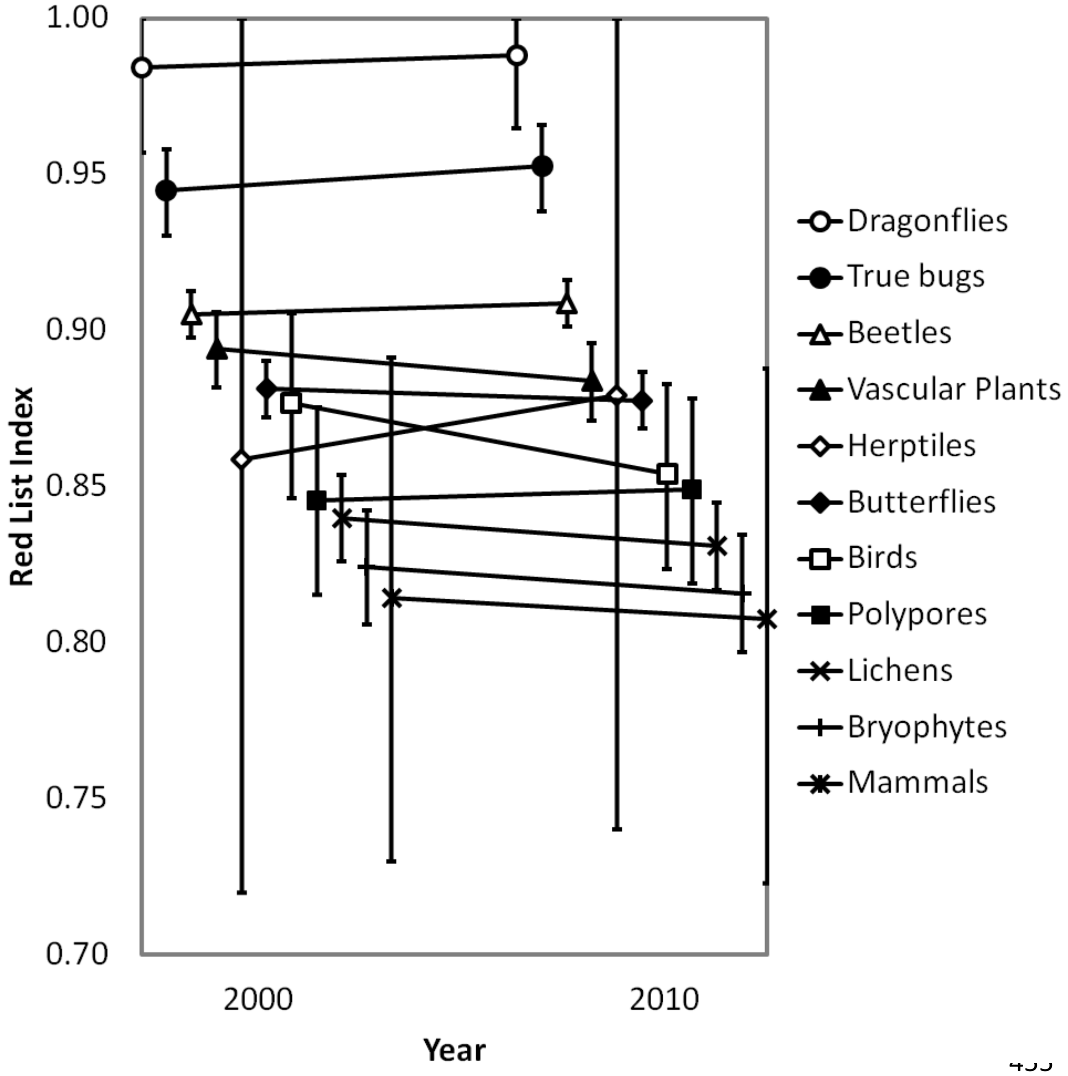
1.00
0.95
0.90
0.85
0.80
0.75
0.70
Red List Index
2000
2010
Year
Dragonflies
True bugs
Beetles
Vascular Plants
Herptiles
Butterflies
Birds
Polypores
Lichens
Bryophytes
Mammals

Figure 1.

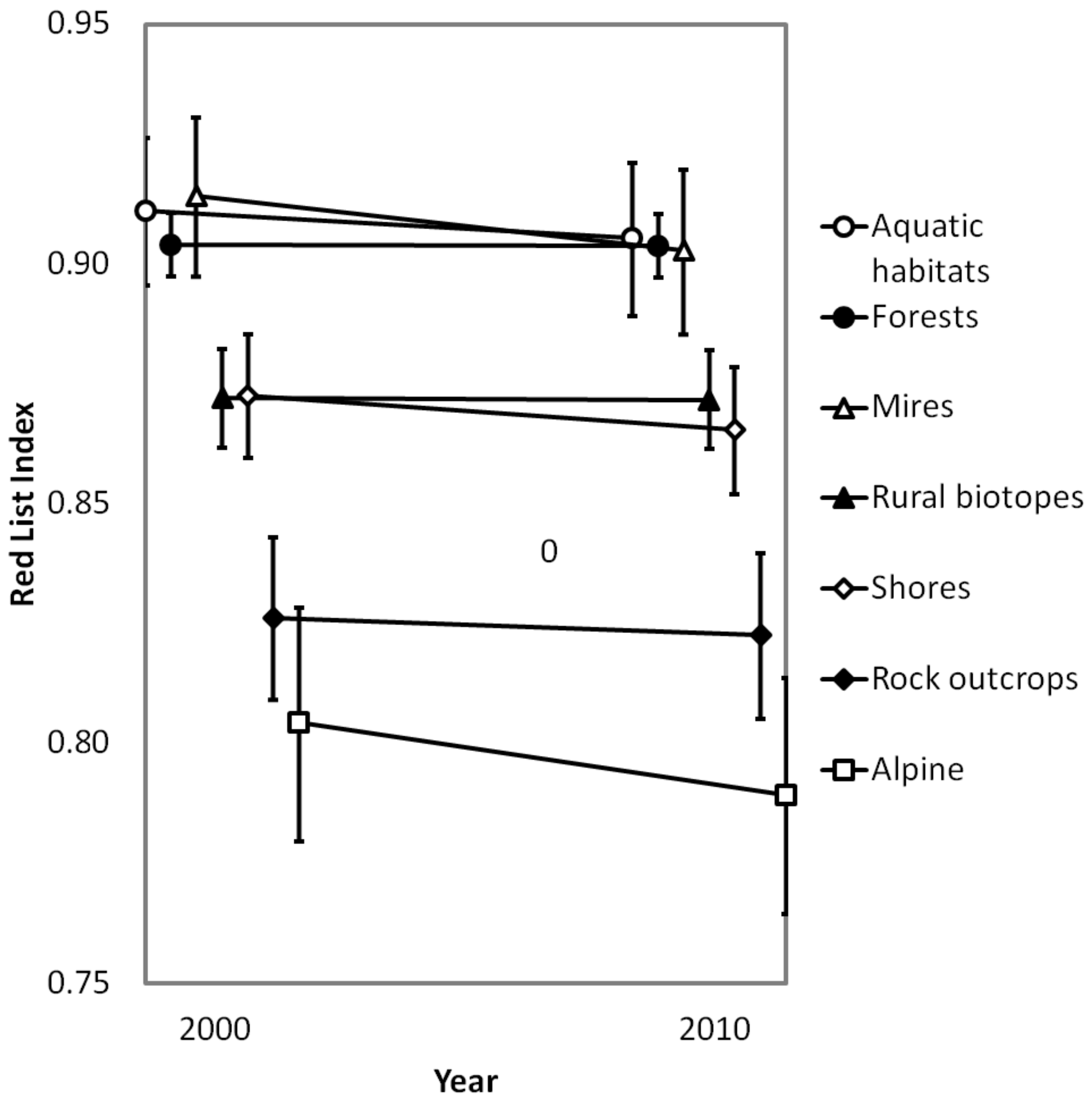
0.95
0.90
0.85
0.80
0.75
Red List Index
2000
2010
Year
0
Aquatic habitats
Forests
Mires
Rural biotopes
Shores
Rock outcrops
Alpine

Figure 2.

Table 1. Number of species known in Finland (Total) by organism groups included in our study, number of taxa included in the red-list assessment of 2010, number of RE, CR, EN, VU, and DD taxa together in 2010, number of taxa excluded from the study because they were Data Deficient or not assessed in 2000 as not having an established population, number of taxa included in the present study and those that genuinely changed red-list category between 2000 and 2010.

Organism group	Total	Assessed (% total)	RE, CR, EN, VU, NT, or DD (% assessed)	Excluded as Data Deficient or other reasons (% assessed)	Included (% assessed)	Genuinely changed (% included)
Beetles (Coleoptera)	3 697	3 416 (92.4)	737 (21.6)	32 (0.9)	3 384 (99.1)	138 (4.1)
Birds (Aves)	249	241 (96.8)	89 (36.9)	4 (1.7)	237 (98.3)	66 (27.8)
Bryophytes (Bryophyta, Marchantiophyta and Anthocerophyta)	906	896 (98.9)	364 (40.6)	23 (2.6)	873 (97.4)	35 (4.0)
Butterflies (Lepidoptera)	2 576	2 313 (89.8)	707 (30.6)	66 (2.9)	2 247 (97.1)	130 (5.8)
Dragonflies and damselflies (Odonata)	55	52 (94.5)	1 (1.9)	1 (1.9)	51 (98.1)	1 (2.0)
Herptiles (Reptilia and Amphibia)	12	10 (83.3)	3 (30.0)	0	10 (100)	1 (10.0)
Lichens (Lichenes)	1 832	1 545 (84.3)	686 (44.4)	153 (9.9)	1 392 (90.1)	59 (4.2)
Mammals (Mammalia)	72	59 (81.9)	22 (37.3)	2 (3.4)	57 (96.6)	4 (7.0)
Polypores (Aphyllophorales and Heterobasidiomycetes)	237	225 (94.9)	95 (42.2)	5 (2.2)	220 (97.8)	9 (4.1)
True bugs (Heteroptera)	506	469 (92.7)	64 (13.6)	6 (1.3)	463 (98.7)	19 (4.1)
Vascular plants (Tracheophyta)	ca. 3 550	1 206 (40.0)	334 (27.7)	9 (0.7)	1 197 (99.3)	67 (5.6)
All species	ca. 13 692	10 432 (76.2)	3 102 (29.7)	304 (2.9)	10 131 (97.1)	529 (5.2)

Table 2. Habitat classification used in Finnish Red Data Books 2001 and 2010 (Rassi et al. 2001; 2010) and corresponding IUCN Habitat classes.

Habitat	Additional explanation	Corresponding IUCN habitat
Alpine	Alpine heaths and meadows above tree-level	Native grassland
Aquatic habitats	Baltic Sea, lakes and ponds, small ponds, rivers, brooks and streams, rapids, spring complexes	Wetlands
Mires	Rich fens, fens, pine mires, spruce mires	Wetlands (subcategory: bogs, marshes, swamps, fens, peatlands)
Forests	Heath forests, herb-rich forests, mountain birch forests	Forests
Rock outcrops	Rock outcrops, including erratic boulders	Inland rocky areas
Rural biotopes and cultural habitats	Seminatural grasslands, wooded pastures and pollard meadows, ditches, arable land, parks, yeards, gardens, roadsides, railway embankments, buildings	Artificial
Shores	Shores of the Baltic Sea, lake shores and river banks	Marine/Intertidal and Marine Coastal/Supratidal

Table 3. The number of taxa in different primary habitats used in the study.

Organism group	Alpine heaths and meadows	Aquatic habitats	Forests	Mires	Rock outcrops	Rural biotopes and cultural habitats	Shores	All habitats
Beetles (Coleoptera)	889	285	1559	72	1	33	545	3 384
Birds (Aves)	36	56	78	20	2	20	25	237
Bryophytes (Bryophyta, Marchantiophyta and Anthocerophyta)	81	83	138	123	269	108	71	873
Butterflies (Lepidoptera)	688	0	1 143	137	27	54	198	2 247
Dragonflies and damselflies (Odonata)	0	46	0	5	0	0	0	51
Herptiles (Reptilia and Amphibia)	1	2	5	0	0	0	2	10
Lichens (Lichenes)	57	3	537	17	600	79	99	1 392
Mammals (Mammalia)	12	7	32	1	0	2	3	57
Polypores (Aphyllophorales and Heterobasidiomycetes)	15	0	198	0	0	0	7	220
True bugs (Heteroptera)	191	44	138	9	1	2	78	463
Vascular plants (Tracheophyta)	346	107	203	129	69	114	229	1 197
All species	2 316	633	4 031	513	969	412	1257	10 131

Table 4. The RLI in 2000 and 2010 and respective change in different groups of organisms and statistical significance of this change.

Group	RLI 2000	RLI 2010	Change	p-value
Beetles	0.905	0.909	0.003	<0.001
Birds	0.877	0.854	-0.023	0.012
Bryophytes	0.824	0.816	-0.008	<0.001
Butterflies	0.881	0.878	-0.004	0.005
Dragonflies	0.984	0.988	0.004	0.372
Herptiles	0.859	0.879	0.020	0.342
Lichens	0.840	0.831	-0.009	<0.001
Mammals	0.814	0.807	-0.007	0.224
Polypores	0.846	0.849	0.004	0.144
True bugs	0.945	0.953	0.008	0.001
Vascular Plants	0.894	0.884	-0.010	<0.001

Table 5. The RLI changes between 2000 and 2010 in different primary habitats (Finnish Red Data Book classification and IUCN Habitat classification) and the statistical significance, statistically significant changes in different organism groups and habitat combinations; and the likely drivers behind the RLI trends shown in the study with supporting notes and references.

Table 6. The changes of RLI for 11 groups of organisms in different primary habitats between 2000 and 2010. Statistically significant combinations are marked with asterisks (* = p < 0.05, ** = p < 0.01, *** = p < 0.001).

Group	Alpine	Aquatic	Forests	Mires	Rock	Rural	Shores
Beetles	0	-0.003	0.006***	-0.003	0	0.004*	0
Birds	-0.04	-0.028	-0.002	-0.08*	0	0	-0.048*
Bryophytes	-0.02***	-0.012**	-0.007**	-0.008**	-0.003*	0	-0.02***
Butterflies	-0.015	0	-0.001	-0.007	0.007	-0.003	-0.016**
Dragonflies	0	0.004	0	0	0	0	0
Herptiles	0	0	0	0	0	0	0.101
Lichens	-0.003	0	-0.017***	-0.012	-0.004***	-0.007	0
Mammals	0	0	-0.006	0	0	-0.017	0
Polypores	0	0	0.003	0	0	0.013	0
True bugs	0	0.005	0.013***	0	0	0.008*	0
Vascular Plants	-0.019***	-0.006*	-0.006	-0.014***	-0.006	-0.009***	-0.014***

*p < 0.05
** p < 0.01
*** p < 0.001

Appendix 1.

The species included in the study, their main habitats and the IUCN threat classification in 2000 (backcasted) and 2010.

Appendix 2.

RLI values for all combinations of taxonomic groups and habitat types (Appendix) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.