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Verifying the predicted risk of extinction based on ecological characteristics

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Abstract

Red List status of species should reflect species extinction risk. Because data are limited and species response has a time lag, species may be threatened by extinction even if they are not Red-Listed. The ability to predict species risk of extinction from ecological characteristics holds promises for proactively targeting conservation measures to species at high risk. In 2005, the risk of extinction from ecological characteristics was predicted for 81 species of Finnish butterflies. Now, after 15 years and two additional national Red List assessments, these predictions are verified. Species with a higher risk of extinction according to the original ecological extinction risk rank (EERR) have indeed deteriorated further as judged by their Red List status, whereas species with a smaller risk of extinction according to EERR retained their Red List status or became more viable. The analysis confirms that predicting the risk of extinction based on ecological characteristics works in practice, and such a complementary approach to Red Listing could help us to advance conservation biology from the crisis discipline toward prognostic conservation practice.

KEYWORDS

butterflies, insects, IUCN, Red List, threatened species

1 | INTRODUCTION

Ecosystem degradation and biodiversity loss are accelerating (IPBES, 2018, 2019). To stop the biodiversity crisis, one of the most important challenges for conservation biologists is to identify the ecological and life history characteristics of species that might predispose them to threats, leading to population declines and—eventually—to extinction (Davidson, Hamilton, Boyer, Brown, & Ceballos, 2009; Kotiaho, Kaitala, Komonen, & Päivinen, 2005). Such knowledge could be used to proactively target conservation and monitoring actions to species, which are not threatened yet, but could become so in the near future (Coulthard, Norrey, & Shortall, 2019; Zettlemoyer, McKenna, & Lau, 2019). Many indices are used to monitor population trends and extinction risks (Butchart et al., 2010), but to our knowledge few attempts have been made to verify the predictive power of the indices.

Red List categories of the International Union for Conservation of Nature (IUCN) reflect species extinction probability, but the underlying criteria are mainly based on species population and range size, as well as changes in them (IUCN, 2012). In real-world, data on population and range size are limited, and thus Red List status of a species may not reflect true extinction risk, or species at the risk of extinction may not be Red Listed at all (Ocampo-Peñuela, Jenkins, Vijay, Li, & Pimm, 2016). Furthermore, species biological traits expose them differently to environmental changes (Cardillo, Mace, Gittleman, & Purvis, 2006), and such changes can affect species with a time lag (Cowlishaw, 1999; Hanski & Ovaskainen, 2002).

The index of ecological extinction risk (EERR) predicts the risk of extinction from ecological characteristics for 81 butterfly species in Finland (Kotiaho et al., 2005). EERR is based on six ecological characteristics (see Methods). We projected the EERR of each species against its Red List status in the 2001 Red List of Finnish Species (see Rassi, Alanen, Kanerva, & Mannerkoski, 2001), which follows the IUCN criteria and classifications (IUCN, 2012). The EERR identified a few species, which were not Red-Listed at the time, although they shared ecological characteristics with Red-Listed species. Similarly, EERR identified a few species, which were Red Listed at the time, although they shared ecological characteristics with species classified as the least concern. Now, 15 years and two Red List assessments (Hyvärinen, Juslén, Kemppainen, Uddström, & Liukko, 2019; Rassi, Hyvärinen, Juslén, & Mannerkoski, 2010) later the original EERR is revisited and analyzed for its predictive power.

2 | METHODS

The original analysis of Kotiaho et al. (2005) was based on six ecological characteristics: niche breadth measured as larval host plant specificity (monophage or polyphage), resource distribution (host plant distribution in Finland), dispersal ability (on the scale 1 to 10, based on expert opinion), adult habitat breadth (number of habitat types used), length of the flight period, and body size (i.e., wingspan).

We analyzed changes in the overall Red List statuses between 2001 and 2019 assessments using Mann–Whitney *U*-test, with the normal approximation Z of the U-statistic and asymptotic two-tailed significance. Response variable was EERR, and the explanatory variable was whether the species' Red List status improved or remained unaltered ($n = 63$), or deteriorated ($n = 18$). The null hypothesis was that the distribution of EERR ranks is similar for the species in these two categories.

To obtain a more detailed understanding of the changes in Red List status of the species with different EERR, we divided the species in eight equally-sized groups based on their EERR. There were 10 species in each EERR group (1–10, 11–20, etc.), except in the last one (EERR 71–81). For each species, we assigned a value from 1 to 5 based on their Red List status, representing critically endangered (CR), endangered (EN), vulnerable (VU), near-threatened (NT), and least concern (LC), respectively. We used the Friedman repeated-measures analysis of variance by ranks to analyze whether the average Red List status of the species across the three Red List assessments (2001, 2010, and 2019) in each of the EERR group has changed. Null hypothesis was that the average ranks across the three Red List assessments are similar; asymptotic two-tailed significance was used.

Pallas' Fritillary (*Argynnis laodice*; EERR 61) was not evaluated in 2001 or 2010 Red List assessments, so the species is included in the current analysis as a species having no change in Red List status. In all analyses, we considered only genuine changes in the Red List status (see IUCN, 2012), that is, changes caused by increased knowledge (1 spp.) or changes in criteria (7 spp.) were considered "no change." The IUCN criteria changed between 2001 and 2010 assessments, so two of the seven species faced genuine changes between 2010 and 2019. These two species were considered as "deteriorated" in the Mann–Whitney test and in the Friedman test between 2010 and 2019.

3 | RESULTS

Altogether 18 (22%) species became genuinely more threatened in 2001–2019, 2 (2%) became less threatened, and 61 (75%) retained their threat status; none of the species went back and forth in the Red List (Table S1). Species which became more threatened since the 2001 Red List had higher ecological extinction risk in the original analysis (i.e., smaller EERR; median $= 20.5$, range $= 54$) than species which retained their Red List status or became less threatened (median $= 48.0$, range $= 80$; Mann–Whitney $Z = -3.64$, $N = 81$, $p < .001$). More specifically, the Red List status of the species in EERR groups 11–20 and 21–30 deteriorated since the 2001 assessment, whereas the Red List status of the species in other EERR groups maintained or improved their status (Figure 1).

4 | DISCUSSION

In general, the original predictions of Kotiaho et al. (2005) have manifested themselves during the past 15 years. Species which had higher extinction risk based on EERR became indeed more threatened, whereas species which had lower extinction risk retained their Red List status (LC) or became less threatened. Even though the Red List status of the species with the highest extinction risk based on EERR (Group 1–10) did not deteriorate

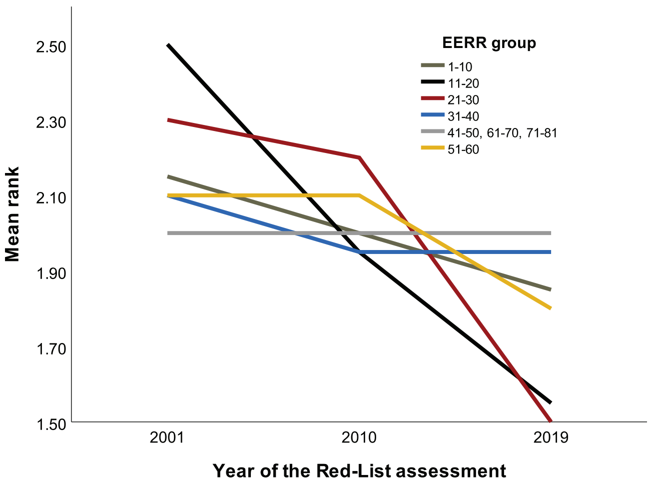

FIGURE 1 Mean rank of species across three Red List assessments for eight ecological extinction risk rank (EERR) groups of the 81 Finnish butterfly species. The group 1–10 indicates the species with the highest ecological extinction risk. Decline in the mean rank indicates deterioration in the average Red List status of that EERR group; absolute values are not informative. Friedman repeated measures analysis of variance by ranks: Group 1–10 $\chi^2 = 1.5$, $p = .47$; Group 11–20 $\chi^2 = 9.6$, $p = .008$; Group 21–30 $\chi^2 = 9.5$, $p = .009$; Group 31–40 $\chi^2 = 0.7$, $p = .72$; Group 41–50 $\chi^2 = 0.0$, $p = 1.00$; Group 51–60 $\chi^2 = 4.0$, $p = .14$; Group 61–70 $\chi^2 = 0.0$, $p = 1.00$; Group 71–80 $\chi^2 = 0.00$, $p = 1.00$; $df = 2$ in all

further, this is not a complete surprise. Some species, for example, were so rare (CR) that the next step in the extinction vortex would have been national extinction. Yet, we stress that no decline in the Red List status does not mean no threat of extinction, that is, many species have retained their high Red List status.

The original EERR identified a few species, such as Frigga's Fritillary (*Boloria frigga*) and Grizzled Skipper (*Pyrgus centaureae*), which were not Red Listed in 2001, although they shared ecological characteristics with Red-Listed species (Kotiaho et al., 2005). Both of these species have since become Red Listed, possibly because of the delayed effect of peat extraction and ditching (Hyvärinen et al., 2019). It is also likely that climate change has further contributed to the decline, because both species have a northern distribution in Finland. The EERR also predicted that Purple Emperor (*Apatura iris*) should not be Red Listed, which, indeed, became true in 2010 (Rassi et al., 2010). Both Purple Emperor and White-letter hairstreak (*Satyrium w-album*), which have become less threatened, have a southern distribution in Finland. These examples support the important role of climate change for range changes of butterflies, and suggest that the location of the species range (e.g., northerness or southerness in a given region) should be taken into account in extinction risk assessments.

Conservation assessment (e.g., IUCN Red List) is an administrative tool. Its use as an indicator of extinction risk in scientific studies must always be treated with caution. However, because Red List status (whether scientifically reliable or not) has real-world political and management consequences, it is important to study how Red List status corresponds to species ecology and changes in distribution and abundance. The present analysis shows that the predicted risk of extinction based on ecological characteristics revealed well the population trends, that is, extinction risk, of butterflies in Finland. Thus, this approach can complement Red Listing, which are based on other (e.g., IUCN) protocols (see also Davidson et al., 2009; Ocampo-Peñuela et al., 2016; Taft, Roff, Komonen, & Kotiaho, 2014). The knowledge about the distribution and abundance of butterflies in Finland is excellent (Hyvärinen et al., 2019), so a similar proactive approach in other regions, where data on species population and range size are more limited, can be even more helpful in targeting conservation measures. In the era of the sixth mass extinction, conservation science must become more proactive (Kotiaho & Mönkkönen, 2017; Soulé, 1985), but—ultimately—proactive conservation requires solid information on species ecology.

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CONFLICT OF INTEREST

The authors have no conflict of interest.

AUTHOR CONTRIBUTIONS

Atte Komonen got the initial idea for re-analysis, Atte Komonen and Janne S. Kotiaho wrote the paper.

DATA AVAILABILITY STATEMENT

All data used in this paper is accessible in Table S1

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SUPPORTING INFORMATION

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