PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B

Phil. Trans. R. Soc. B (2005) **360**, 255–268
doi:10.1098/rstb.2004.1583
Published online 28 February 2005

Using Red List Indices to measure progress towards the 2010 target and beyond

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The World Conservation Union (IUCN) Red List is widely recognized as the most authoritative and objective system for classifying species by their risk of extinction. Red List Indices (RLIs) illustrate the relative rate at which a particular set of species change in overall threat status (i.e. projected relative extinction-risk), based on population and range size and trends as quantified by Red List categories. RLIs can be calculated for any representative set of species that has been fully assessed at least twice. They are based on the number of species in each Red List category, and the number changing categories between assessments as a result of genuine improvement or deterioration in status. RLIs show a fairly coarse level of resolution, but for fully assessed taxonomic groups they are highly representative, being based on information from a high proportion of species worldwide. The RLI for the world's birds shows that that their overall threat status has deteriorated steadily during the years 1988–2004 in all biogeographic realms and ecosystems. A preliminary RLI for amphibians for 1980–2004 shows similar rates of decline. RLIs are in development for other groups. In addition, a sampled index is being developed, based on a stratified sample of species from all major taxonomic groups, realms and ecosystems. This will provide extinction-risk trends that are more representative of all biodiversity.

Keywords: indicators; birds; amphibians; IUCN Red List; threatened species; extinction-risk

1. IUCN RED LIST

The World Conservation Union (IUCN) has published lists of species at risk of extinction since the 1950s, compiling these as Red Data Books since the 1960s and as Red Lists since the 1980s. Initially, species were assigned to qualitatively defined categories. To improve objectivity and consistency of application (Fitter & Fitter 1987) the IUCN Species Survival Commission initiated the development of quantitative criteria in 1989. After several rounds of review and revision, a system was adopted in 1994 (IUCN 1994), with further revisions published in 2001 (IUCN 2001).

There are three principal categories for species at high risk of extinction: critically endangered, endangered and vulnerable. Species are assigned to a category if they meet the appropriate quantitative threshold for at least one of five criteria (table 1). Four criteria are based on the size and rate of decline of the population and/or geographical range, with the fifth relating to quantitative models of extinction-risk such as population viability analyses. Precise information is not essential to apply the criteria: assessors can use expert knowledge along with the best information available to make estimates about the relevant parameters, so long as the uncertainties are explicitly specified (IUCN 2001). Species close to qualifying for the thresholds for vulnerable are classified as near threatened (although there are no definitive quantitative thresholds for this category, guidelines are given). Extinct species are categorized as extinct in the wild (if populations remain in captivity) or extinct (if there is no reasonable doubt that the last individual has died). In addition, some critically endangered species (currently just among birds and amphibians) are identified as possibly extinct (if they are probably, but not certainly, extinct; hence also 'possibly extinct in the wild'; BirdLife International 2004*a*). The remaining categories are least concern, data deficient (where there is inadequate information to make a direct or indirect assessment of a species risk of extinction against the criteria) and not-evaluated (IUCN 2001). Thus, the categories for assessed, extant species can be ranked in order of increasing extinction-risk from least concern, near threatened, vulnerable, endangered to critically endangered.

In recent years, the IUCN Red List has been developed into a global programme, currently overseen

One contribution of 19 to a Discussion Meeting Issue 'Beyond extinction rates: monitoring wild nature for the 2010 target'.

Table 1. Simplified overview of thresholds for the IUCN Red List criteria.

criterion	critically endangered	endangered	vulnerable	qualifiers and notes
A1: reduction in population size	≥90%	≥70%	≥50%	over 10 years/3 generations in the past, where causes are reversible, understood and have ceased
A2–4: reduction in population size	≥80%	≥50%	≥30%	over 10 years/3 generations in past, future or combination
B1: small range (extent of occurrence)	<100 km^2	<5000 km^2	<20 000 km^2	plus two of (a) severe fragmentation/few localities (1, ≤5, ≤10), (b) continuing decline, (c) extreme fluctuation
B2: small range (area of occupancy)	<10 km^2	<500 km^2	<2000 km^2	plus two of (a) severe fragmentation/few localities (1, ≤5, ≤10), (b) continuing decline, (c) extreme fluctuation
C: small and declining population	<250	<2500	<10 000	mature individuals. Continuing decline either (1) over specified rates and time periods or (2) with (a) specified population structure or (b) extreme fluctuation
D1: very small population	<50	<250	<1000	mature individuals
D2: very small range	N/A	N/A	<20 km^2 or ≤5 locations	capable of becoming critically endangered or extinct within a very short time
E: quantitative analysis	≥50% in 10 years/3 generations	≥20% in 20 years/5 generations	≥10% in 100 years	estimated extinction-risk using quantitative models, e.g. population viability analyses

by four partner organizations: the IUCN Species Survival Commission, BirdLife International, NatureServe and the Center for Applied Biodiversity Science at Conservation International. Additional partners are being recruited, in particular to provide plant and marine expertise. The programme has two principal aims: (1) to identify and document those species most in need of conservation attention if global extinction rates are to be reduced; and (2) to provide a global index of the state of degeneration of biodiversity.

The IUCN Red List is now widely recognized as the most objective and authoritative system for classifying species in terms of their risk of extinction (Lamoreux *et al*. 2003; Hambler 2004). Its strengths include: (i) the classification system is explicit, credible and can be applied at global and national scales to all taxa except micro-organisms, including in data-poor situations; (ii) there are comprehensive assessments for a number of taxon groups and regions; (iii) there is an effective, extensive and expanding network for gathering data and carrying out assessments; (iv) a well-organized programme exists with increasing capacity to store and analyse data and disseminate information; (v) it has clear relevance as a key measure of the state of biodiversity (species extinctions); and (vi) it already has a high profile and is widely accepted and used by decision-makers. The short-comings of the Red List include: (i) its categories provide a fairly coarse level of resolution of status; (ii) it provides no discrimination between species at low threat levels; and (iii) invertebrate and plant groups are inadequately represented at present.

2. USING THE RED LIST AS A BIODIVERSITY INDICATOR

The first attempt to use the IUCN Red List as an indicator of trends in the status of biodiversity was by Smith *et al*. (1993), who examined the rate at which the number of species on the IUCN Red List increased, and the net movement of species between categories. This general approach has been questioned on the grounds that: (i) the IUCN Red List categories are subjective; (ii) taxonomic treatment is uneven, with listings biased towards attractive, spectacular, high-profile or better-known species; and (iii) most species move between categories because of changes in knowledge or taxonomy, not as a consequence of genuine improvement or deterioration in status (e.g. Cuarón 1993; Burgman 2002; Possingham *et al*. 2002; but see Lamoreux *et al*. 2003).

The first of these problems was addressed by the introduction of quantitative and objective categories and criteria (IUCN 1994, 2001). The second problem can be overcome by calculating indices only for taxonomic groups in which all species have been comprehensively assessed and reassessed (as shown here for birds and amphibians), or by developing indices that sample representatively from diverse taxonomic groups (see below). The third problem can also be addressed, and we explore this, and the methods used for calculating RLIs, in detail below.

(a) *Distinguishing genuine status changes*

There are a number of reasons why species may change Red List categories between assessments. Since 2001, a 'reason for change' code has been assigned to differentiate these. This coding has recently been refined through developing the Red List Indices (RLI) for birds (Butchart *et al.* 2004). Five mutually exclusive codes are used: (i) 'Recent genuine status change', applied to species that have undergone a genuine improvement or deterioration in status since the last assessment. (ii) 'Genuine status change since first assessment', applied to species that have undergone a genuine improvement or deterioration in status in the time period since the first complete assessment, but before the last assessment. This code denotes genuine changes in status that were not detected at the time they occurred. (iii) 'Knowledge', applied to species re-categorized owing to new information (which may have existed before the last assessment, but was only available to the assessors after it). (iv) 'Criteria revision', applied in cases when species changed category owing to revisions to the definitions of the IUCN Red List criteria (IUCN 2001). (v) 'Taxonomy', applied in cases when species changed category owing to taxonomic 'lumping' or 'splitting' or for newly described species. Only the first two kinds of change—genuine status change—are used for calculating the indices (Butchart *et al.* 2004).

(b) *Calculating RLIs*

RLIs are calculated from the number of species in each category in each assessment, and the number of species changing categories as a result of genuine improvement or deterioration status. Specifically: (i) For species assessed in two consecutive assessments, the total number of species in each Red List category in the earlier assessment is calculated (excluding data deficient, extinct and possibly extinct, but incorporating retrospective category adjustments owing to genuine status changes identified since the first assessment: see Butchart *et al.* 2004). The totals are multiplied by a category weight (see below), and the products are summed to give a total score for the assessment. (ii) The net number of genuine changes (losses and gains) between assessments in each category (including changes from critically endangered to extinct, possibly extinct and extinct in the wild) is calculated, multiplied by the category weight and summed. From this figure, the percentage change in the total score is calculated. (iii) The index value of the previous assessment (set to 100 for the first assessment: 1988 for birds and 1980 for amphibians) is then scaled up or down by this percentage change to give the new value (see Butchart *et al.* 2004 for further details). Mathematically, the method can be described as follows: where T is total score, $N_{c(t_i)}$ is the number of species in category c at time t_i, where t_i is the year of the i-th assessment (assessments are not necessarily made every year); W_c is the weight for category c; P is proportional genuine change; I_{t_i} is the value of the index at time t_i; Cat(t_i,s) is the category of species s at time t_i; W_c is the weight for category c; $G_s = 1$ if the change (from $t_{(i-1)}$ to t_i) in category of species s is genuine (otherwise $G_s = 0$).

$$T_{t_i} = \sum_c W_c N_{c(t_i)},$$

$$P_{t_i} = \sum_s [(W_{c(t_i,s)} - W_{c(t_{i-1},s)})G_s]/T_{t_{i-1}},$$

$$I_{t_i} = I_{(t_{i-1})}(1 - P_{t_i}),$$

where $I_{t_{i-1}} = 100$ for the first year of assessment.

Categories can be weighted in a number of ways. We examined two: an equal-steps approach and an extinction-risk approach. In the equal-steps approach the weights range from 0 for least concern, 1 for near threatened, 2 for vulnerable, 3 for endangered, 4 for critically endangered and 5 for extinct, extinct in the wild and possibly extinct to reflect the ordinal ranks of the categories. Here, each step from least concern towards extinct indicates that at least one measure of extinction-risk has become worse. This approach is simple and the trends in the resulting index are driven by a relatively large number of species, producing a more robust and representative index. This is because a species moving from least concern to near threatened contributes just as much to the changing score as a critically endangered species going extinct, but the number of species in each category (and the number of species moving in and out of each category) is disproportionately larger in the lower threat categories. The main disadvantage is that the weights merely reflect the linear hierarchy of categories. However, the steps between lower categories (e.g. near threatened to vulnerable) translate to smaller increases in extinction-risk than steps between higher categories (e.g. endangered to critically endangered). The extinction-risk approach accounts for this by basing weights on the relative extinction-risk associated with each category, ranging from 0.0005 for near threatened and 0.005 for vulnerable to 1.0 for extinct (see Butchart *et al.* 2004).

The most significant difference between the approaches is the effect of status changes in less threatened or non-threatened species. With the equal-steps approach, the index is heavily influenced by (relatively numerous) movements of species among the lower categories, such as near threatened and vulnerable. With the extinction-risk approach, the index is largely influenced by (relatively few) movements of species in and out of critically endangered. For example, if a vulnerable species improves in status and becomes near threatened, and at the same time, a critically endangered species becomes extinct, the RLI based on equal-steps weights registers no change, but the index based on weights derived from extinction risks shows a substantial decrease. How these differences are interpreted depends on what the index is taken to represent. Down-listing of a vulnerable species to near threatened might represent a very substantial population increase, whereas extinction of a critically endangered species might represent the loss of very few individuals. In terms of genetic diversity, the latter is arguably more significant; as a pointer to wider biodiversity trends, the former might be as, or more, important.

We used the equal-steps approach for calculating the RLI for complete taxonomic groups, and for subsets of

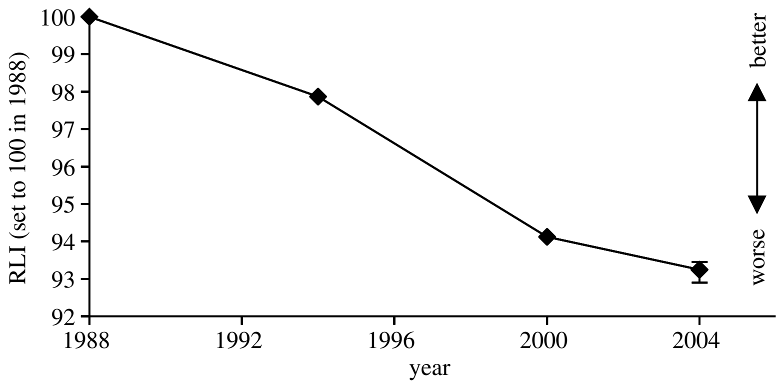

Figure 1. The Red List Index for all bird species, 1988–2004 ($n=250$ genuine status changes/2469 species in categories extinct in the wild to near threatened, in at least one assessment). Error bars for 2004 RLI value based on estimated number of genuine status changes for 2000–2004 not yet detected owing to information time-lags (see text for further details).

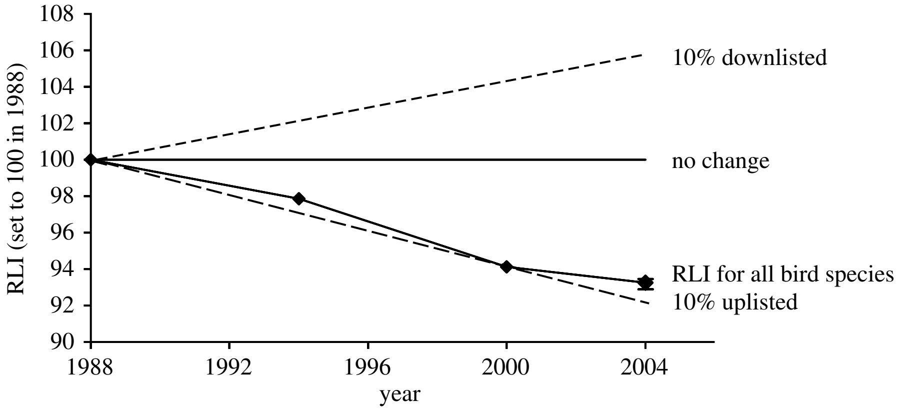

Figure 2. The Red List Index for all bird species, 1988–2004 ($n=250/2469$ species), with hypothetical indices showing trends if zero species had changed category, and if 10% of species in the categories from near threatened to critically endangered had been up-listed to a higher category of threat or down-listed to a lower category of threat over the period.

species, for example, in particular realms or ecosystems, because the number of species moving between the higher threat categories (which effectively drive trends in the RLI weighted by extinction-risk) was too small to be meaningful in disaggregated indices. For birds, only 23% of all genuine status changes (58 species in total) involved moves in between the highest threat categories. However, we used the weights based on relative extinction-risk for examining trends in the species closest to extinction.

(c) *Calculating error bars*

Using the following method, we calculated the possible range of error associated with the latest (2004) RLI value owing to time-lags before genuine status changes are detected (see §6). We estimated how many such undetected category changes there may be for 2000–2004 using the 1994–2000 data (information gathering has improved considerably in recent years, so comparisons with time-lags for the 1988–1994 period are not meaningful). In total, 128 genuine changes for 1994–2000 were identified in 2000, and an additional 17 (13.3%) were identified in the subsequent 4 years. This suggests that an additional six category changes (13.3% of 45 genuine status changes identified in 2004) may be belatedly detected for 2000–2004. We randomly selected six species from the 9453 species that did not undergo category changes from 2000 to 2004, with a maximum of two species per category. We ran 10 000 simulations of six species moving to categories of higher extinction-risk, with probabilities for each number of category steps set by the distribution of category changes for 35 'up-listed' species in 2000–2004. The maximum value for P (proportional genuine change) from these simulations gave the lower error bar for the 2004 RLI value. Similarly, we ran 10 000 simulations of six species moving to categories of lower extinction-risk (with probabilities for each number of category steps set by the distribution of category changes for 10 down-listed species in 2000–2004), and took the minimum value for P to give the upper error bar (see Butchart *et al.* 2004).

For the subset of species plotted, sample sizes in the figure legends give the total number of category changes owing to genuine status changes (but note that a small number of bird species underwent genuine status changes in more than one period between assessments), and the total number of species in categories EW, CR, EN, VU and NT in at least one assessment during the period (and that are taxonomically recognized at present). For amphibians, the total number of data deficient species is also given for each subset, as this forms a substantial proportion in some cases (for birds it is $<1\%$ in all cases).

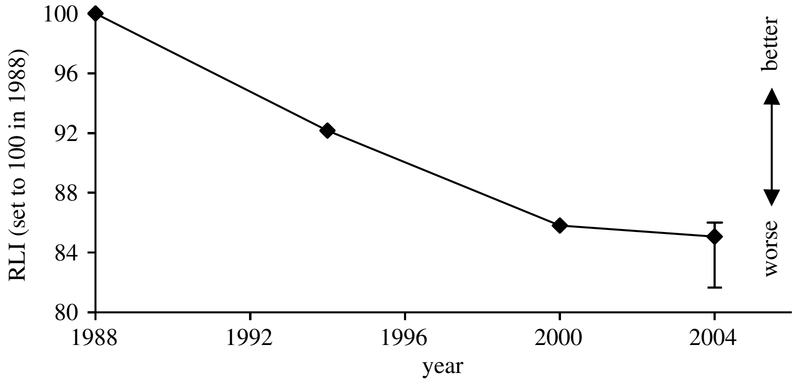

Figure 3. The Red List Index weighted by extinction-risk for all bird species, 1988–2004 ($n = 250$ genuine status changes/2469 species in categories extinct in the wild to near threatened, in at least one assessment). Error bars for 2004 RLI value based on estimated number of genuine status changes for 2000–2004 not yet detected owing to information time-lags (see text for further details).

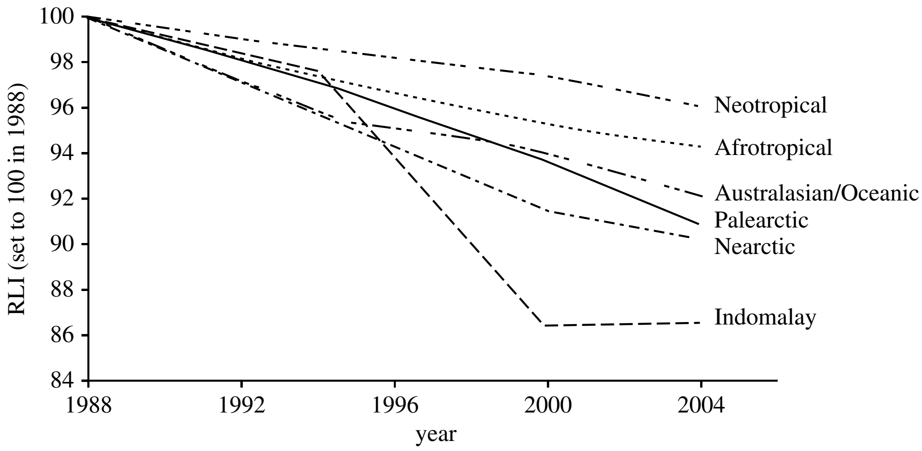

Figure 4. Red List Indices for birds for 1988–2004 in different biogeographic realms. Sample sizes: Afrotropical = 41 genuine status changes/394 species in categories extinct in the wild to near threatened, in at least one assessment; Indomalay = 100/585, Nearctic = 9/92, Neotropical = 49/834, Australasian/Oceanic = 53/614, Palaearctic = 34/238.

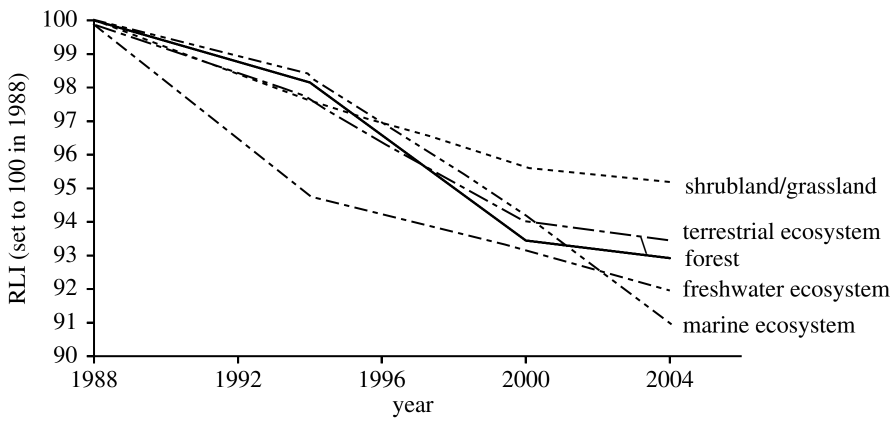

Figure 5. Red List Indices for birds for 1988–2004 in the marine, freshwater and terrestrial ecosystems, and for birds in forest and shrubland/grassland habitats. Sample sizes: marine = 12 genuine status changes/133 species in categories extinct in the wild to near threatened, in at least one assessment; freshwater = 31/226, terrestrial = 206/2329, forest = 169/1513, shrubland/grassland = 45/481.

3. RESULTS FROM BIRDS AND AMPHIBIANS

Birds have been completely assessed for the IUCN Red List four times (Collar & Andrew 1988; Collar *et al.* 1994; BirdLife International 2000, 2004*a*), and birds were the first group for which RLIs were developed (Butchart *et al.* 2004). For amphibians, the first global assessment has recently been completed (IUCN-SSC, CI/CABS and NatureServe 2004). In addition, an IUCN Red List category for each amphibian species in 1980 was retrospectively assigned ('back-casted') by considering the 2004 category and information on the spread of disease, habitat degradation and loss, the

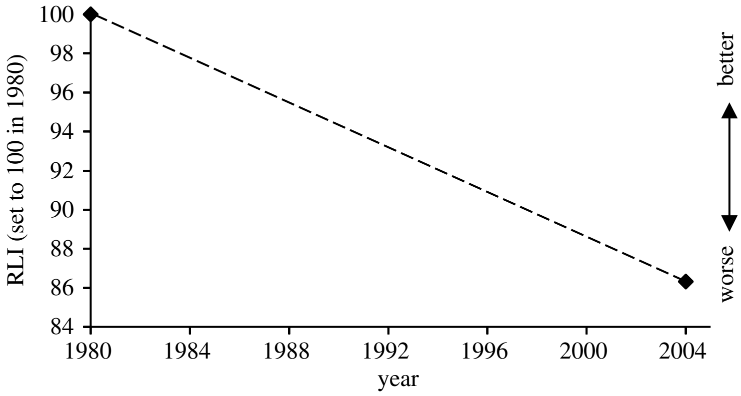

Figure 6. A preliminary Red List Index for all amphibian species for 1980–2004 (retrospectively assessed; $n=496$ genuine status changes/2225 species in categories extinct in the wild to near threatened, in at least one assessment; 1294 data deficient/5709 extant species).

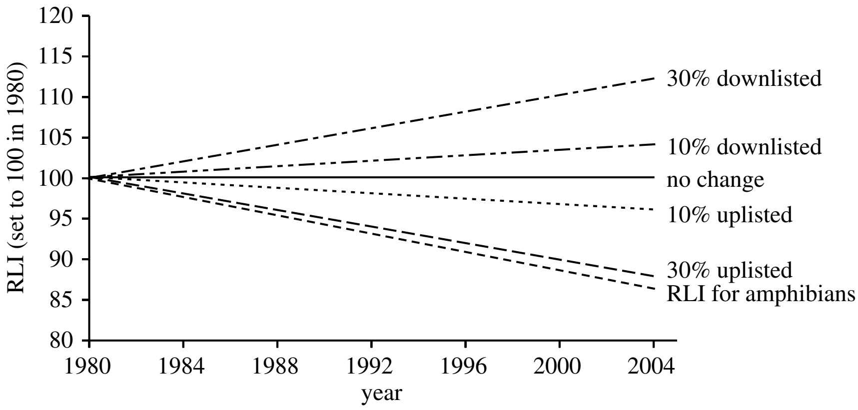

Figure 7. A preliminary Red List Index for all amphibian species for 1980–2004 (retrospectively assessed; $n=496/2225$ species), with hypothetical indices showing trends if zero species had changed category, and if 10 or 30% of species in the categories from near threatened to critically endangered had been up-listed to a higher category of threat or down-listed to a lower category of threat over the period.

introduction of alien species and knowledge of population trends. A conservative approach was adopted, and category changes were only recorded as having taken place when the evidence was considered to be strong. In cases of significant uncertainty, it was assumed that no change in category had occurred. Given the uncertainty over these back-casted assessments, the RLI for amphibians is represented with a dotted line in figures 6–11.

The RLI for birds shows that there has been a steady and continuing deterioration in the threat status of the world's birds between 1988 and 2004, with an overall change in the index value of −6.90% over this period (figure 1). Zero change would indicate that the average status of all bird species was the same as in 1988. To put this into context, if 10% of species in categories near threatened to critically endangered had deteriorated in status enough to be up-listed one category to a higher threat category between 1988 and 2004, the index would have changed by −7.8% (figure 2). The error bars for the 2004 RLI value (based on the projected number of genuine status changes for the 2000–2004 period that is yet to be detected owing to information time-lags: see above) show that the estimated recent RLI trends are likely to be fairly robust.

Examining trends in the most threatened species, the RLI weighted by extinction-risk shows an apparent levelling out in the rate of deterioration since 2000 (although the error bars indicate that in the next few years the belated discovery of genuine status changes for this period could reduce this effect; figure 3). This is because, for the species closest to extinction, the number that deteriorated in status was almost balanced by the number improving in status owing to conservation action. However, it should be noted that the deteriorating species included two critically endangered species that became extinct (or possibly extinct) in the wild during this period (Hawaiian Crow *Corvus hawaiiensis* and Spix's Macaw *Cyanopsitta spixii*).

Disaggregated RLIs show that the threat status of birds has deteriorated worldwide with a more-or-less similar rate and proportional extent in the Nearctic, Neotropical, Palaearctic, Afrotropical and Australasian/Oceanic realms. The Indomalay realm shows a steeper rate of deterioration during the 1990s (figure 4). This was a result of intensifying destruction of forests in the Sundaic lowlands of Indonesia, which escalated in the late 1990s leading to predictions of almost total loss of lowland forest in Sumatra by 2005 and in Kalimantan by 2010 (Holmes 2000; BirdLife International 2001). Because of these increasing rates of habitat loss, many

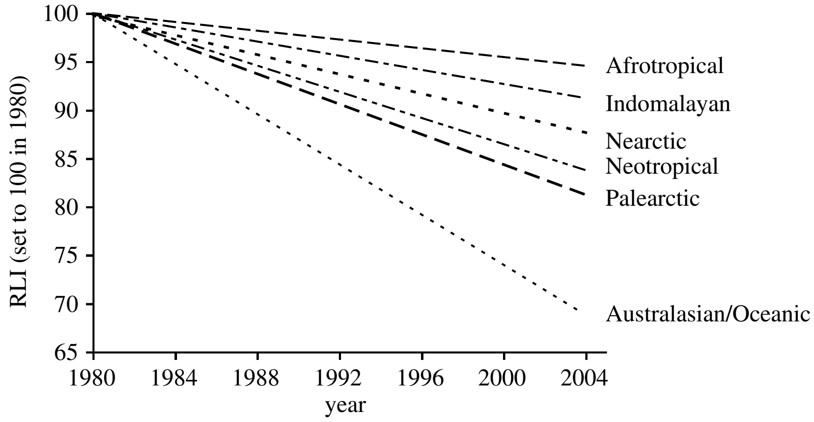

Figure 8. Preliminary Red List Indices for amphibians for 1980–2004 (retrospectively assessed) in different biogeographic realms. Sample sizes: Afrotropical = 29 genuine status changes/287 species in categories extinct in the wild to near threatened, in at least one assessment (205 data deficient/951 extant species); Indo-Malayan = 60/399 species (226 DD/917 extant species); Nearctic = 29/118 species (22 DD/329 extant species); Neotropical = 332/1260 species (628 DD/2818 extant species); Australasian/Oceanic = 38/88 species (177 DD/558 extant species); Palaearctic = 36/148 species (55 DD/450 extant species).

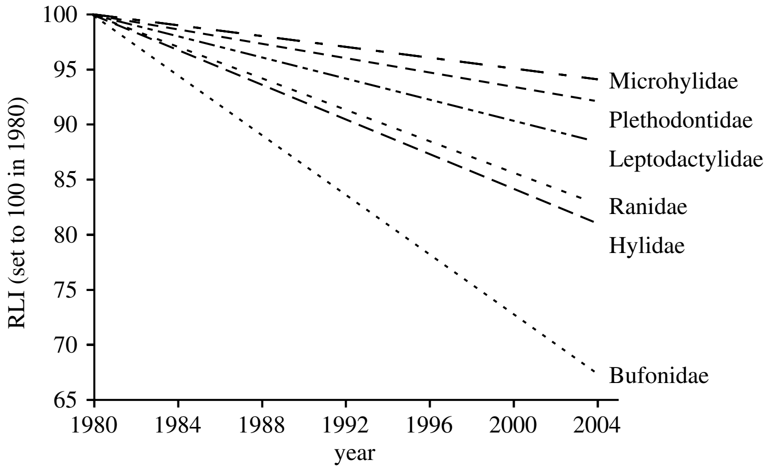

Figure 9. Preliminary Red List Indices for selected amphibian families for 1980–2004 (retrospectively assessed). Sample sizes: Bufonidae: 106 genuine status changes/233 species in categories extinct in the wild to near threatened, in at least one assessment (59 data deficient/456 extant species); Leptodactylidae: 121/584 species (220 DD/1122 extant species); Hylidae: 68/241 species (171 DD/856 extant species); Ranidae: 56/222 species (132 DD/648 extant species); Microhylidae: 10/89 species (153 DD/413 extant species); Plethodontidae: 34/204 species (54 DD/347 extant species).

species were up-listed to higher categories of threat under criterion A (rapid population declines). However, worldwide there has been a significant deterioration in the threat status of birds of shrubland/grassland habitats as well as forest, and in the two other major ecosystems (freshwater and marine), indicating that birds in a broad spectrum of environments are deteriorating in status (figure 5).

A preliminary RLI for amphibians, based on the assessments in 2004, and retrospective classifications for 1980, shows that the threat status of the world's amphibians has also deteriorated substantially (figure 6). The index value changed by −13.7% over this period. The net decline is equivalent to approximately 30% of species in each 1980 category from near threatened to critically endangered being up-listed by one category (figure 7). However, the rate of deterioration is likely to have been underestimated: a conservative approach was adopted in identifying genuine deteriorations between 1980 and 2004. Furthermore, 22.5% of amphibians are listed as data deficient, and with better information many of these may well prove to be threatened and to have undergone serious declines through this period. A formal RLI for amphibians will be released in 4–5 years when all species are assessed again.

The preliminary RLI for amphibians in different realms shows that species in the Australasian/Oceanic realm have undergone the steepest deterioration in status, followed by those in the Palaearctic and Neotropical realms (figure 8). However, the steep rate of deterioration in the Australasian/Oceanic realm may be influenced by the fact that a large proportion of species are listed as data deficient in this region, particularly in eastern Indonesia and Papua New Guinea (31.6% compared to a mean of 21.6% in all other realms). It is unlikely that many of these have undergone severe declines, because the majority are in the family Microhylidae (61.6% compared with 3.9% in all other realms) which is one of the groups least

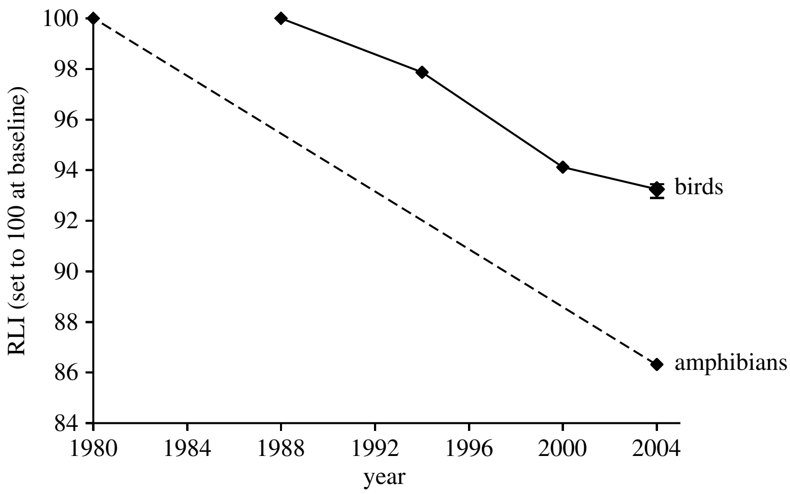

Figure 10. The Red List Index for all bird species for 1988–2004 and a preliminary Red List Index for all amphibians for 1980–2004 (retrospective assessment). Sample sizes: birds: $n=250$ genuine status changes/2469 species in categories extinct in the wild to near threatened, in at least one assessment; amphibians: $n=496/2225$ species; 1294 data deficient/5709 extant species.

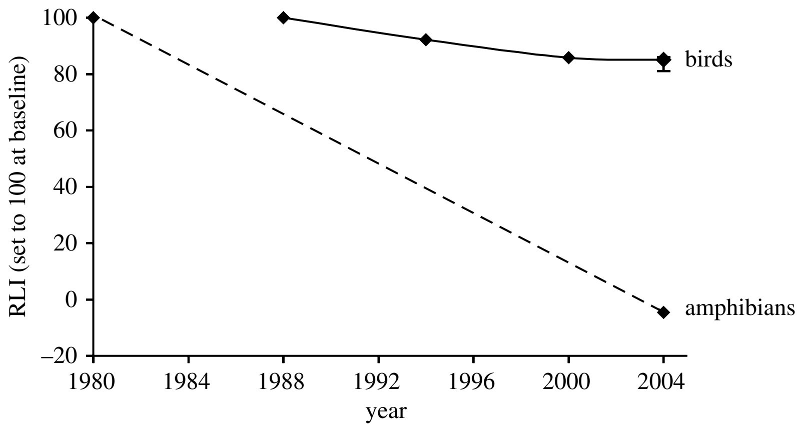

Figure 11. The Red List Index weighted by extinction-risk for all bird species for 1988–2004 and a preliminary Red List Index weighted by extinction-risk for all amphibian species for 1980–2004 (retrospective assessment). Sample sizes: birds: $n=250$ genuine status changes/2469 species in categories extinct in the wild to near threatened, in at least one assessment; amphibians: $n=496/2225$ species; 1294 data deficient/5709 extant species.

affected by the disease chytridiomycosis (implicated in the recent catastrophic decline of many amphibians). Data deficient species are excluded when calculating the index value, giving any genuine status changes a greater proportional significance. Further information is likely to show that the majority of these Australasian/Oceanic data deficient species have not undergone significant status changes over the period, giving an adjusted RLI for this realm that shows a smaller rate of decline. Once further information becomes available, it is predicted that the decline in the Neotropics will prove to have been more severe than that in the Australasian/Oceanic realm. The severity of declines in the Palaearctic realm has been driven largely by the increasing levels of exploitation of amphibians in China during this period.

Some families of amphibians have undergone more serious declines than others (figure 9). Toads (Bufonidae) have shown the steepest rate of deterioration in threat status, and this is probably a reflection of the high level of susceptibility of the genus *Atelopus* to chytridiomycosis (Lötters *et al.* 2003).

The RLI for birds (1988–2004) and the preliminary index for amphibians (1980–2004) show remarkably similar slopes, changing by −0.422% per year for birds and −0.571% per year for amphibians (figure 10). Many bird and amphibian species that underwent status changes during these time periods will have been impacted in a similar way by the same habitat loss. However, amphibians have also been severely impacted by chytridiomycosis. It is presumably coincidence that the proportion of amphibians that have changed status as a result of this threat, more-or-less balances the proportion of birds impacted by other threats, such as invasive species: a particularly significant threat on oceanic islands (BirdLife International 2004*b*), where there are few amphibians. The RLI weighted by extinction-risk for amphibians shows a much steeper decline than that for birds (figure 11). This is because the proportional rate at which amphibians moved into the highest threat categories was greater than for birds.

4. INTERPRETING RLIs

RLIs illustrate the relative rate at which species in a particular group change in overall status, based on population and range size and trends as quantified by Red List categories. Hence, they provide a measure of the rate at which species in a particular group change in their relative projected extinction-risk (the net rate at which they are slipping towards extinction).

How can biodiversity indicators be interpreted in relation to the CBD's target of reducing the rate of loss of biodiversity by 2010? The interpretation is different for measures of the state of biodiversity (for example, total area of remaining forest) and measures of the rate-of-change in this state (for example, annual percentage forest loss). For indices based on proportional change in a measure (plotted on a negative scale as with the RLI), if the measure is one of state, a significant diminution in downward trend would show that the target has been met. However, if the measure is one of rate-of-change of state, the target is not met until we see a positive trend, not just a decelerating decline. Some of the Red List criteria are based on absolute population size or range size, while others are based on rates of decline in these values or combinations of absolute size and rates of decline. These criteria are used to assign species to Red List categories that can be ranked according to relative projected extinction-risk, and the RLI is calculated from changes between these categories. Hence, RLI values relate to the rate at which species are slipping towards extinction at particular points in time. To show that the 2010 target has been met, the RLI must therefore show a positive trend. A downward trend, even if becoming less steep, shows that the slide of species towards extinction is accelerating, not slowing down. The negative trends in the RLI values for birds (figure 1) and amphibians (figure 6) show that in 2004, we are losing biodiversity at an increasing rate, at least as far as these groups are concerned.

It is important to note that owing to the somewhat arbitrary nature of the weights applied to each category to calculate the score, the percentage decline in the index value (e.g. 6.9% for birds between 1988 and 2004) is not directly comparable with percentage declines reported for population-based indices such as the Living Planet Index (Loh 2002), or the UK headline indicator for wild bird populations (Gregory *et al.* 2003).

5. IDENTIFYING FACTORS DRIVING TRENDS IN THE RLI

The RLI for a particular taxonomic group illustrates global trends within the group, and as demonstrated with the bird and amphibian data presented here, indices can be disaggregated for biogeographic realms and ecosystems. Trends in these indices have to be interpreted in light of the threatening processes impacting the species concerned. This is made easier because all Red List assessments are accompanied by documentation of the threats impacting the species and the actions proposed and underway for the species. These are categorized according to standard classification schemes (authority files: IUCN 2004*a*), so that, for example, comparisons can be made between taxonomic groups or regions. Some species undergoing genuine change in status occur in more than one biogeographic realm or ecosystem. When disaggregating the index, the change is allocated to the realm(s) and ecosystem(s) where the threatening process or status change has occurred. For example, Saker Falcon *Falco cherrug* occurs in the Palaearctic, Indomalay and Afrotropical realms. However, recent declines (which led to its up-listing to endangered in 2004) were driven by factors operating on the breeding grounds in Central Asia (unsustainable levels of exploitation for the falconry trade; BirdLife International 2004*a*), so the genuine change was allocated only to the Palaearctic realm. By contrast, Black-browed Albatross *Thalassarche melanophrys* declined during the same period as a result of incidental capture in commercial longline fisheries in oceans in the Afrotropical, Neotropical and Australasian/Oceanic realms (BirdLife International 2004*a*), and so this genuine change was incorporated into the RLI trends for all three realms. In this way, RLI trends can be interpreted through matching up the genuine status changes with the processes and pressures causing such changes.

6. STRENGTHS AND WEAKNESSES OF RLIs

There are two key issues relating to the strengths and weaknesses of the RLIs compared with other potential biodiversity indicators: representativeness and resolution.

(a) *Representativeness*

The most significant strength of the RLIs described here is that they are highly representative, being based on assessments of a high proportion of species in a taxonomic group across the world. The Red List process is an effective way to make meaningful inferences from data that are imprecise or incomplete. Thus, RLIs can incorporate information even from species that are rare, localized, or difficult to survey, including those most susceptible to extinction. Hence, the RLIs presented here incorporate trends for 99.2% of all bird species (excluding 78 data deficient species out of 9788 extant species) and 77.3% of amphibian species (excluding 1294 data deficient species out of 5709 extant species). In contrast, most other global indicators based on population estimates are derived from sampled data biased towards common, well-studied species in the developed world, particularly Europe and North America. For example, in a global index based on data from 936 amphibian populations from 37 countries around the world, 89% of populations (835) were from Europe or North America, and just 2.2% (21) were from Asia and 5.5% (51) from South/Central America (Houlahan *et al.* 2000).

It could be argued that, even for species that have been assessed for the Red List and not placed into the data deficient category, information on some of these species may be too imprecise or inaccurate to detect

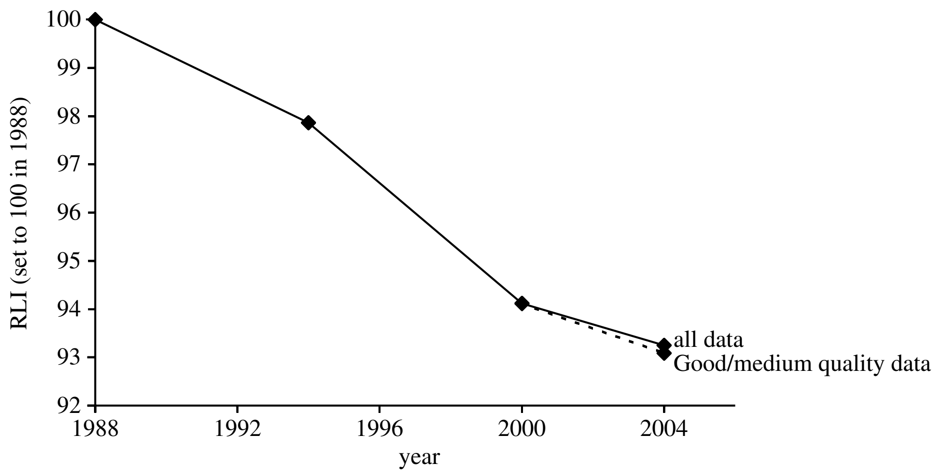

Figure 12. The Red List Index for all bird species, 1988–2004 ($n=250$ genuine status changes/2469 species in categories extinct in the wild to near threatened, in at least one assessment), and the RLI calculated for 2000–2004 based only on species with high quality data ($n=45$ genuine status changes in 2000–2004/701 species in categories extinct in the wild to near threatened in 2000 and/or 2004).

Table 2. Data quality definitions for parameters used in Red List assessments for birds, and the number of threatened bird species qualifying owing to good, medium or poor quality data.

data quality	definition	no. (%) threatened bird species
good	population size and trend: 'based on reliable and complete or representative quantitative data' range size: 'based on polygon boundary largely defined by localities/areas in which the species is known currently (>1980) to occur, and/or by areas of suitable habitat at appropriate elevations where it is thought that it is highly likely to occur'	281 (23.2%)
medium	population size and trend: 'based on reliable but incomplete or partially representative quantitative data' range size: 'based on polygon boundary largely defined by localities/areas in which the species is known currently (>1980) to occur, or to have occurred in the recent past (>1970), and/or by areas of suitable habitat at appropriate elevations where it is thought that it is likely to occur'	446 (36.8%)
poor	population size and trend: 'based on qualitative information, but no (or potentially unreliable/unrepresentative) quantitative data' range size: 'based on polygon boundary largely defined by localities/areas in which the species is known to occur, or to have occurred, and/or by appropriate buffers and/or geographic features where it is thought to occur'.	486 (40%)

genuine status changes, and hence the RLI under-represents the real extent of overall trends. It is true that relatively large numbers of bird species changed categories in 1994 and 2000 owing to improvements in knowledge and improved consistency of interpretation of information against the Red List criteria (62% of all category changes during that period). This was because of the introduction of quantitative criteria for assigning species to categories in 1994 (Collar *et al.* 1994; IUCN 1994), and the mapping of all threatened species and more rigorous justification for near threatened status in 2000 (BirdLife International 2000). However, by 2000–2004, only 6.7% of threatened and near-threatened species changed category owing to improved knowledge. Nevertheless, a small proportion of species may be sufficiently poorly known that there is uncertainty over their status, and whether this has changed over time. This could introduce a potential bias (and an over-optimistic RLI trend) if well-studied species (with better data and hence more certain Red List assessments) were more likely to be those receiving conservation attention, and hence improving in status (or at least deteriorating less rapidly). To test this we recalculated the 2004 RLI value for birds using only species with high quality data. For critically endangered, endangered and vulnerable bird species all data used in Red List assessments (population size, population trend, range size, etc.) are scored for data quality. For each species assessed in 2000 and 2004, we identified the highest data quality code associated with any parameter triggering a criterion for the category at which the species is listed (many species trigger multiple criteria for the category for which they qualify). In total, 60% of species were categorized based on good (23.2%) or medium (36.8%) quality data (see definitions in table 2). If species with poor quality data are excluded from the 2000–2004 RLI trend calculations, the 2004 RLI value becomes 93.1 compared to 93.2 (figure 12), which is within the calculated range of error bars associated with the 2004 RLI value (see below). This indicates that the subset of species with poorer quality data introduce no substantial bias into the calculated RLI value.

It is also worth noting that it is accurate categorization of species that is important for the Red List and RLI. Even imprecise and inaccurate estimates of particular parameters (e.g. population size) will often accurately place species in the correct category owing to the broad nature of the categories. For example, any population numbering between 2500 and 9999 mature individuals (with specified declines rates or population structure) is correctly classified as vulnerable.

Although RLIs show high representativeness within taxonomic groups, relatively few groups, not representative of species diversity as a whole, have so far been completely assessed, and fewer still on a regular basis. Red List coverage is constantly improving, so this problem will diminish, but by 2010, RLIs based on complete assessments will likely be available only for a relatively small set of taxa. To overcome this problem, a sampled index based on a broad spectrum of taxa is also being developed (see below).

(b) *Resolution*

RLIs show a fairly coarse level of resolution of status changes as a consequence of the broad nature of Red List categories. The size, trend or distribution of populations may have to undergo quite substantial changes before crossing the criteria thresholds to qualify for a higher or lower Red List category, and hence before changing the RLI value. For example, a species' population may have to decline from almost 10 000 individuals to fewer than 2500 individuals, or its range contract from 20 000 km^2 to less than 5000 km^2 before the species is moved from vulnerable to endangered. This is inherent in using the Red List categories rather than more precise parameters such as estimates of population size. For this reason, RLIs are very complementary to population-based indices: the former are derived from potentially cruder data that can be collected for nearly all species in a taxonomic group, while the latter are based on much more detailed information that can only be collected for a small (and often biased) subset of species.

In some cases, status changes can be incorporated in the index without delay, because the Red List criteria allow species to be assessed as threatened on the basis of justified projected declines (criterion A3). Thus changes in category can reflect new or emerging threats and small population or range changes in anticipation that these will exceed the appropriate criteria thresholds over specified time-frames.

However, there may be time-lags between a species' population or range changing and this being reflected in the RLI value because of delays before the change is detected or becomes known by assessors. This is potentially more problematic, but several factors act to mitigate it. The Red List Programme has a large and expanding network of many thousands of scientists across the world providing detailed and up-to-date information for an increasing number of species. Furthermore, with improving channels of communication (in particular, the increasing use of the worldwide-web to solicit information, e.g. BirdLife's web-based globally threatened bird discussion forums: BirdLife International 2004*c*), we expect that such delays will diminish, and retrospective adjustments to the index values will decrease in future. The bird data support this supposition. Whereas just 42% of 60 genuine status changes between 1988 and 1994 were detected in 1994 (with 43% detected during 1994–2000 and 15% detected during 2000–2004), 88% of 145 changes during 1994–2000 were detected in 2000, and just 12% were detected in the subsequent 4 years. Using the data from the 1994 to 2000 period (because information gathering has improved considerably since 1988–1994), we can estimate the likely number of genuine status changes for 2000–2004 that have not yet been detected, and hence estimate the possible degree of error associated with the 2004 RLI value. The results show that it may be an under- or overestimate by 0.21–0.37% (figure 1): a small and acceptable margin of error.

We recommend that RLIs are calculated from reassessments of the status of all species within a taxonomic group at intervals of 4–5 years. This interval is an appropriate balance between a number of factors: (i) the need for a sufficiently long interval to facilitate detection of status changes and to allocate these to periods between assessments; (ii) the practicalities of carrying out global assessment exercises involving hundreds or thousands of experts and many thousands of species; and (iii) the need for indices that are up-to-date and with an adequate degree of temporal resolution.

7. HOW WILL CONSISTENT, ACCURATE AND REPRESENTATIVE DATA BE DELIVERED REGULARLY IN FUTURE?

The IUCN Red List Programme was developed in part to ensure that systematic Red List assessments of major taxonomic groups were carried out regularly, and to expand the taxonomic breadth of such assessments. The programme appoints Red List authorities for all taxonomic groups included on the Red List. These are responsible for ensuring that all species within their jurisdiction are correctly and regularly revaluated against the IUCN Red List categories. Evaluations have to be supported with adequate documentation and must be carried out in as consultative manner as possible. To ensure consistency in the application of the Red List criteria between different taxonomic groups and over time, detailed guidelines have been produced (Red List Standards and Petitions Subcommittee 2003) and an informal users group meets regularly to agree on common standards and approaches in Red List assessments.

Red List assessments are open to query. It is the role of Red List authorities to respond to such queries on the basis of the available evidence and information. If the parties are unable to reach mutual agreement, the matter may be referred to a Red List standards and petitions committee to help adjudicate. However, such situations are rare and nearly all assessments are the result of consensus based on the best available documentation.

In order to develop representative biodiversity indicators from the IUCN Red List, a major expansion of the taxonomic coverage is a very high priority. Here, we have presented a RLI for birds (1988–2004) and a preliminary index for amphibians (1980–2004). By 2010, birds and amphibians will have been reassessed once more, indices will have been developed for mammals (1996–2005 at least). A number of other groups will have been completely assessed at least once, including reptiles (*ca* 8000 species, assessment initiated in 2004), freshwater fish (*ca* 10 000 species, initiated in 2003), sharks, rays and chimeras (*ca* 1000 species, to be completed in 2005) and freshwater molluscs (*ca* 5000 species, initiated in 2004). Similar targets exist for various plant groups, although there is the much larger target of obtaining a preliminary assessment of all plant species by 2010, which is part of the global strategy for plant conservation adopted by the sixth conference of the parties of the Convention on Biological Diversity in April 2002. SSC has also set in motion processes to identify priority taxonomic groups of plants, invertebrates and marine organisms to ensure a more representative coverage on the Red List (IUCN 2004*b*). When there are a number of completely assessed taxonomic groups being regularly reassessed, an aggregated RLI will be calculated.

8. DEVELOPMENT OF A SAMPLED RLI

The RLI described above requires that all species within a taxonomic group are assessed at regular intervals. Ideally, this approach would be applied to all major taxonomic groups in order to gain insight into global trends in extinction-risk. However, this becomes impractical when considering regular and complete assessments of some of the large and less well-studied groups such as fungi (*ca* 70 000 species), plants (*ca* 280 000 species) and insects (*ca* 950 000 species). One way of addressing this problem is to use a random or representative sample of species from a broad set of major taxonomic groups. Such a sampled approach is currently being developed with the intention that the base structure will be implemented by 2010 and preliminary results will be available for a number of taxonomic groups. The purpose of the sampled RLI is to provide a measure of the changing relative extinction-risk of all species, major taxonomic groups, biogeographic realms and three main ecosystems. Design of the sampled approach has to take many factors into account, including limitations of data availability and resources. Not all of these difficulties have been resolved yet, but here we introduce some of the main issues.

(a) *Selection of taxonomic groups*

The world's species can be grouped at many different taxonomic levels from genus to kingdom. For the purposes of this index, a relatively small number of taxonomic groups that are representative of the world's species-level biodiversity are required. Limiting the number of taxonomic groups will help to ensure that there is sufficient data per taxonomic group and that the system is manageable and affordable. However, there will be an inevitable trade-off between the groups that are selected and data availability. Further work is required to define the groups to be selected.

(b) *Stratification*

Ideally, the sample of species should be representative of all taxonomic groups, biogeographic realms and ecosystems, and of the Red List category of species within each of these. One way to ensure this would be to classify all species into these classes, and then to sample at random within them. However, there are a number of practical difficulties with this approach. Firstly, there is much uncertainty over the number of species in many groups and the total number of species that exist (May 1992), making it difficult to stratify across taxonomic groups. Taking the number of described species is not a satisfactory solution, as the proportion of species described varies greatly across taxonomic groups (Groombridge & Jenkins 2002). Lists of named species do not even exist for some groups, raising further problems. Secondly, the natural distribution of species across Red List categories, biogeographic realms and ecosystems is unknown for many taxonomic groups. Patterns for poorly known groups cannot be extrapolated from well-known groups because the available information indicates that there is substantial variation between taxa (e.g. the proportion of species in the Palaearctic realm is 17% for mammals but 9% for birds). Estimates could potentially be derived by selecting and analysing a random subset of each group. However, this would require substantial resources.

(c) *Sampling*

To produce an index that is representative of all biodiversity, one approach would be to select similar proportions of species from all strata based on major taxonomic group, realm and so on. This would allow the index to be calculated as described above without any adjustment for sampling intensity. However, such an approach would necessitate an impractically large number of species from groups such as insects. An alternative option is to select species in proportions that vary among strata. A simple example of this is to take equal numbers across taxonomic groups, Red List categories and realms (but not ecosystems because the distribution of taxonomic groups between ecosystems varies greatly). Using this approach, the sample size would be smaller, and data-gathering would therefore be more feasible. It would be desirable to take the uneven sampling intensity into account when producing indices for aggregated strata in order to overcome bias towards smaller taxonomic groups, threatened species and species-poor regions. However, as noted above, the distribution patterns of species across taxonomic groups, categories and realms are not yet adequately known to permit this at present. Taking equal numbers of species per stratum would not necessarily maximize the precision obtained from a given amount of effort, so a further possibility is to use a design that varies sample sizes across strata with the aim of maximizing precision. This could take into account factors such as the effort required to assess species in different strata. Simulations could be carried out on the bird data in order to test the precision of different designs.

Excluding not-evaluated species and data deficient species would introduce bias into the sample if these are unrepresentative of all species. This problem could be overcome by including not-evaluated and data deficient as strata, evaluating a random sample of not-evaluated species for the first time, and gathering sufficient new data to reassess a random sample of data deficient species. However, this would be impractical, expensive and time-consuming for many species. Furthermore, it would provide only the first data points for such species, so information on changes in the index would only be available once such species had been assessed for the second time. Nevertheless, such an approach would be necessary to produce an unbiased RLI incorporating information from incompletely assessed groups, unless we assume that species that have already been assessed have the same chance of changing their extinction-risk as those that have not.

(d) *Sample size*

It is important to identify the smallest number of species per taxonomic group that provides a relatively accurate indication of overall trends in extinction-risk. This facilitates the inclusion in the sampled index of taxonomic groups for which only a small proportion of species have been assessed and it minimizes the resources required. We used the data on birds to explore the effect of sample size on the variability of the RLI. We tested sample sizes from 120 to 480 species, using the 2000 and 2004 Red List assessments. For each sample size, we randomly sampled an equal number of species from each category and each realm. In cases where this was not possible (because, for example, there were only eight critically endangered bird species in the Palaearctic in 2000 that were also assessed in 2004), we randomly sampled species from other realms until the correct number was sampled from each category. We repeated the sampling 10 000 times for each sample size, and calculated the mean and standard deviation of the change in the RLI value (and repeated this for the RLI weighted by extinction-risk). This indicates that a sample size of about 300 species per taxonomic group (which would be practical and affordable for most groups) would give sufficient resolution to detect important changes in the status of species: a standard deviation of 0.5% for the RLI and 1.9% for the RLI weighted by extinction-risk. The higher standard deviation of the latter is largely owing to the larger absolute change in the index value weighted by extinction-risk.

(e) *Implementation*

Further work is required to resolve some of the issues outlined here. Once the set of species has been selected, it is anticipated that they will be reassessed every 4–5 years to allow the sampled RLI to be updated. Ideally, the identity of the species will not be publicized in order to avoid special conservation attention being focused on them (thus rendering them less representative of the non-assessed species). It may be necessary to ensure that assessors reassess a larger number of species, including the selected ones, in order not to identify the selected species. Transparency of the process and RLI need not be compromised by confidentiality over the identity of the species contributing to the sampled RLI. Funding is currently being sought and, by 2010, it is hoped that an effective programme will be delivering data for regular updates of the sampled RLI based on an increasingly comprehensive taxonomic sample.

9. CONCLUSIONS

We have shown here, using data from birds and amphibians, how information from the IUCN Red List can be used to calculate RLIs that are robust, temporally sensitive, representative and comprehensive. These provide unique baseline data on the rate of loss of biodiversity against which progress towards meeting the CBD 2010 target can be judged. They also allow finer-scale resolution of trends in particular biogeographic realms, ecosystems and habitats, and provide indications of major underlying causes of biodiversity loss. In time, the number of taxonomic groups for which RLIs can be calculated will expand. In addition, a sampled RLI based on species from a broad range of taxonomic groups is in development to provide trends of extinction-risk more representative of all biodiversity. RLIs provide one measure by which to judge success or failure in addressing global biodiversity loss.

For helpful comments on the methods and earlier drafts we thank A. Balmford, N. Collar, U. Gärdenfors, R. Green, R. Gregory, N. Leader-Williams, J. Pilgrim and A. van Strien. For help with data management we thank M. Sneary, M. Balman and M. Evans. We thank the Netherlands Ministry of Agriculture, Nature and Food Quality (LNV), Directorate-General for International Cooperation, Netherlands Ministry of Foreign Affairs (DGIS), National Science Foundation, Swiss Development Corporation and the Rufford Foundation for funding some of the work presented here. We are grateful to many hundreds of experts and organizations who contributed information used in Red List assessments over many years which have allowed this analysis to be possible. In particular, we acknowledge the pioneering contribution made by Nigel Collar on Red Listing the world's birds.

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