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Prioritizing non-marine invertebrate taxa for Red Listing

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Abstract The IUCN Red List of threatened species is biased towards vertebrate animals, a major limitation on its utility for overall biodiversity assessment. There is a need to increase the representation of invertebrates (currently 21 % of species assessed on the List; <1 % of all invertebrates). A prioritisation system of terrestrial and freshwater groups is presented here, categorising taxa by species richness, assessment practicality, value for human land use and bioindication, and potential to act as conservation flagships. 25 major taxonomic groupings were identified as priorities, including the Annelida, Arthropoda, Mollusca, and Onycophora. Of these, the high-level taxa that emerge as highest priorities are Odonata (dragonflies and damselflies), Araneae (spiders), Mantophasmatodea (heelwalkers), Plecoptera (stoneflies), non-marine Mollusca (Bivalvia and Gastropoda), Trichoptera (caddisflies), Coleoptera (beetles), Lepidoptera (moths and butterflies), Oligochaetes (earthworms), Orthoptera (grasshoppers and crickets), Decapoda (crayfish, crabs, shrimps) and Diptera (flies). Of these Red Listing is well advanced for Decapoda, freshwater Mollusca and Odonata. This leaves eight higher taxa with currently a minimum or patchy Red List assessment coverage. We recommend that Red List assessments in

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future focus on these groups, as well as completion of assessments for terrestrial Molluscs and Odonata. However, we also recommend realism, and as some of groups are very large, it will be necessary to focus on subsets such as certain functionally important or charismatic taxa or on a sampled subset which is representative of a larger taxon.

Keywords Conservation status · Strategic planning · Conservation planning · Biodiversity · Extinction

Introduction

Current rates of species extinction are estimated to be 48–476 times the background rate (Baillie et al. 2004), with some taxa having considerably higher rates (e.g. amphibians—McCallum 2007). These estimates are imprecise owing to major problems with the data (Stork 2009). Firstly, there are no clear consensus estimates of the number of extant species, with estimates varying from 1.8 to 111.7 million (Wilson 1987; Mora et al. 2011; Costello et al. 2012). Identifying extinctions with certainty is difficult (Roberts 2006; McKelvey et al. 2008), and the estimates are questionable even for some well studied, low diversity taxa such as birds (Pimm et al. 2006). Methods of extrapolating extinction rates from existing data such as rates of habitat loss are also contentious (Stork 2009; He and Hubbel 2011; Evans et al. 2011). With little idea of the rate of extinction, it is not surprising that the levels of threat to the surviving species are even more uncertain.

Currently, the International Union for the Conservation of Nature (IUCN) Red List of threatened species (IUCN 2013) contains assessments of the status of 71,576 species. This represents only 4 % of described species and 0.9 % of all species [using Mora et al.'s (2011) estimate], and is strongly biased towards vertebrates (52 % of assessed species).

The Sampled Red List Index (SRLI) is an established methodology which aims to quantify the state of global biodiversity using a sampled subset of species from different taxa (Baillie et al. 2008). It provides a means of evaluating threat in less well studied groups, and is completed for dragonflies (Clausnitzer et al. 2009) freshwater crabs and crayfish (Cumberlidge et al. 2009), freshwater molluscs. Butterflies are currently being assessed for the SRLI (Lewis and Senior 2011). European saproxylic beetles have also been assessed, although not sampled randomly (Nieto and Alexander 2010), and assessment is almost completed for freshwater molluscs. This is one way of attempting to assess speciose groups, especially given the relative paucity of invertebrate assessments contributing to the Red List (Cardoso et al. 2011b).

Some of the groups which are currently under-represented on the Red List are of particular concern as they play major roles in ecosystems, notably fungi and many invertebrate groups (Koh et al. 2004; Thomas et al. 2004; Dunn 2005). The importance of invertebrates is highlighted by the case of pollinators, where there have been declines in populations of some of the most significant pollinators (Biesmeijer et al. 2006; Cameron et al. 2011; Williams and Osborne, 2009; Gill et al. 2012), with evidence of a corresponding decline in the abundance of insect pollinated plants (Biesmeijer et al. 2006). Conservation of other invertebrates with important ecological and economic functions (pollinators, water filterers, soil formers, biocontrol species etc.) is potentially of great economic as well as ecological value. Yet determining these values is currently hampered by a lack of available information on the status of most species.

In 2010, the 'Barometer of Life' (BoL) was proposed (Stuart et al. 2010) to provide an overview of the status of biodiversity, free from data biases. This aims to monitor the status of 160,000 species, selected across various taxa, including a provisional target of 45,344 invertebrates. The biases to be avoided by the BoL are primarily taxonomic (principally the dominance of vertebrate assessments), but also include biases towards certain geographical areas and ecosystems. Ideally the listing would be representative of all taxa, regions and systems. Some attempts have been made to reduce biases through comprehensive listing of some major groups (mammals, birds, amphibians, corals, sharks, cycads), major groups in selected ecosystems (dragonflies, freshwater fish, freshwater molluscs, freshwater crabs, freshwater shrimps, and crayfish), sampled listings (reptiles, butterflies, dung beetles) and geographical listings (e.g. European saproxylic beetles). However, even these are restricted taxonomically, ecologically and/or geographically. In addition to these assessment projects coordinated by IUCN and its Red List partners, assessments are added to the Red List by submission of small numbers of assessments by individual experts.

Current trends in assessment rate mean that the BoL target would not be reached for at least 200 years, therefore additional larger-scale (taxonomic and geographical) assessments are needed. This requires determining which invertebrate groups should be the focus for comprehensive or sampled assessments. This is particularly important where significant funding needs to be sought for assessment. As noted by Stuart et al. (2010), some taxa such as nematodes and sponges are generally too poorly known taxonomically to allow meaningful assessment, except in specific geographical areas on a particular taxonomic subset. This means that selection of the 45,344 invertebrate species cannot be merely an ad hoc process, as this might lead to the creation of yet more biased data sets. Instead, a system of prioritisation is needed. Prioritisation of non-marine invertebrate groups was undertaken by the

Table 1 Diversity of non-marine invertebrates and their Red List status (version 2013.2)

	Described species[a]	RL species[b]	Out of date
Porifera	150	0	0
Cnidaria	100	0	0
Myxozoa	3	0	0
Platyhelminthes	7,500	1	1
Micrognathozoa	1	0	0
Entoprocta	2	0	0
Nemertina	27	6	6
Rotifera	2,300	0	0
Acanthocephala	1,150	0	0
Annelida	10,650	9	8
Mollusca	36,000	5,768	1,310
Bryozoa	50	0	0
Gastrotricha	300	0	0
Nematoda	12,000	0	0
Nematomorpha	230	0	0
Tardigrada	800	0	0
Onychophora	167	11	7
Arthropoda	1,203,951	7,584	915
Chelicerata	112,427	35	18
Crustacea	15,992	2,907	289
Myriapoda	11,999	32	1
Hexapoda	1,063,533	4,610	607
Collembola	8,163	0	0
Protura	816	0	0
Diplura	975	0	0
Archaeognatha	506	0	0
Zygentoma	554	0	0
Ephemeroptera	3,124	3	3
Odonata	6,042	2,752	21
Grylloblattodea	32	1	1
Dermaptera	1,933	6	1
Blattodea	7,570	25	0
Isoptera	2,800	4	0
Mantodea	2,427	2	1
Zoraptera	36	0	0
Mantophasmatodea	17	0	0
Orthoptera	23,830	236	74
Phasmida	3,046	8	0
Embiidina	457	0	0
Plecoptera	3,713	4	4
Psocoptera	5,611	0	0
Phthiraptera	5,135	1	1
Thysanoptera	5,938	0	0
Hemiptera	102,183	5	5
Neuropterida	6,011	0	0
Coleoptera	389,487	527	68
Strepsiptera	613	0	0
Diptera	156,774	7	7
Mecoptera	400	0	0
Siphonaptera	2,082	0	0
Trichoptera	14,548	4	4
Lepidoptera	158,396	722	265
Hymenoptera	153,088	302	151

[a] Derived from Chapman (2009), Mayer and Oliveira (2013), Zhang (2013)

[b] *Source*: www.iucnredlist.org (accessed 24 April 2014)

Invertebrate Conservation Sub-Committee of the IUCN/Species Survival Commission, and is described and discussed here.

Review of Red List invertebrates

Currently (IUCN Red List version 2013.2), the Red List comprises 15,911 invertebrate species, 13,376 of which are non-marine (including 2,245 'out of date' assessments—i.e. those that are at least 10 years old and should be updated). This represents 25 % of Red Listed animals, although non-marine invertebrates probably make up about 96 % of described animal species (Gerlach et al. 2012). Even within invertebrates, there are marked differences between taxa in the proportion that are Red Listed (Table 1). Of those phyla that include assessed species, the least well represented are the polyphyletic 'Platyhelminthes' (only 0.01 % of described species assessed) and the Annelida (0.09 %). However, arthropods are the most significant weakness, with only 0.76 % of species assessed out of the more than one million described (numbers from Chapman 2009). Conversely, the most completely assessed phylum of invertebrates in freshwater and on land is the Nemertina (22 %, although the vast majority of marine species have not been assessed and non-marine species number only 27). Of the highly speciose arthropods, most assessments are in the freshwater Crustacea (18 %) and among the hexapoda, the Odonata, principally as a result of the latter being taxonomically well resolved compared to other invertebrates (Clausnitzer et al. 2009; Kalkman et al. 2008), which resulted in their inclusion in the SRLI and the IUCN/SSC Freshwater Assessment (Clausnitzer et al. 2012). There is then a huge gap, with the Odonata being followed far behind by geographically patchy and taxonomically individualistic assessments of Lepidoptera, Coleoptera, Orthoptera and Hymenoptera (only 0.006–0.24 % of described species in those orders).

Prioritization of new listings

The Red List can be, if used in parallel with other data, a useful tool for identifying conservation action and funding priorities. However, in view of its proportional bias to vertebrates, there is now a need to increase the representation of lesser known groups such as fungi and invertebrates. Individual assessments continue to be made, and large scale assessments are being incorporated through the IUCN/Species Survival Commission initiatives, especially the Freshwater Assessment (Darwall et al. 2011) and the IUCN/SSC/Zoological Society of London's SRLI initiative (Butchart et al. 2005). However, both approaches still leave major phyletic and ecological gaps to be addressed. To help identify these gaps, we undertook an evaluation of invertebrate groups to identify taxa (at various taxonomic levels) as priorities for assessment, or for incorporation into other assessment programmes. This prioritisation aims to identify those groups which have to date been largely overlooked. However, this prioritisation process is not without biases itself, if only because of the extreme variation in knowledge of different taxa or the availability of experts who are able to provide assessments. At the outset, our prioritisation attempts to avoid a priori assumption concerning which taxa may be most at risk of extinction. In turn, a scientifically robust Red List should then identify objectively which taxa are most at risk.

Priorities were determined by combining three categories: species richness and assessment practicality; importance in terms of value for human land use and bioindication; and potential to act as an invertebrate conservation flagship. The third of these categories was introduced as a practical measure; Red Listing of relatively charismatic flagship groups is likely to generate interest and attract funding that can then be applied to assessment of other taxa.

Species richness and assessment practicality

Species richness and assessment practicality were based on existing evaluations of species richness and use approximate numbers of recorded species rather than the estimated total species number (assumed to be considerably higher, e.g. ±70 % of Nematoda and Arthropoda await description—Hamilton et al. 2010). These numbers were grouped under assessment practicality.

(A) Taxa with low species numbers are often phylogenetically isolated groups of evolutionary interest (e.g. Onychophora, Grylloblattodea and Mantophasmatodea), may be relatively easy to assess, and can be considered to have high priority. The significance of these phylogenetically important taxa has been reviewed elsewhere (e.g. Crandall et al. 2000; Cadotte and Jonathan Davies 2010) At the other extreme, highly speciose taxa constitute a major part of biodiversity and need to be well represented on any robust BoL. Accordingly, these are also given high priority. Taxa were grouped into high priority for assessment (exceptionally species rich groups for which sampled assessments are needed, and species poor groups which would be amenable to comprehensive assessment), medium priority (groups which are species rich but not the richest or which could be partially assessed using a thematic or SRLI approach), and finally, those of lowest priority (intermediate levels of species richness which would neither capture a major component of taxonomic biodiversity nor have so few species that a full assessment is feasible nor be particularly amenable to an SRLI approach). Species number data are modified from Chapman (2009) and Kalkman et al. (2008) and scored as follows:

<150 [easily assessed] = score 5
151–1,500 [cut-off for full listing in SRLI] = 4
1,501–5,000 = 3
5,001–100,000 = 4
>100,000 = 5

(B) Stability of taxonomy has a major influence on assessment practicality. Stable taxonomy makes assessment relatively straightforward, whereas unstable taxonomy causes confusion. Also, the availability of a taxon list or database, such as the Orthoptera Species File (Eades et al. 2012) or the World Spider Catalogue (Platnick 2014), is an asset. Although a species list is not essential for assessment, it greatly facilitates the process and is essential for the SRLI. Inevitably, taxonomy changes constantly (even in the relatively well studied vertebrates, e.g. reptiles: Torstrom et al. 2014) and molecular taxonomic techniques are leading to major revisions in many taxa. In order to assess the degree of stability we used an index of taxonomic completeness dividing the number of described species by the estimated total number of species. As this is based on current numbers and estimates, it is not necessarily accurate, but provides an indication of the current view of taxonomic completeness. Estimated totals were derived from the Freshwater Animal Diversity Assessment (Balian et al. 2008) for aquatic taxa and from Chapman (2009) for terrestrial taxa.

1 = described/total <0.1—outdated, and with few specialists, so that revision is unlikely in the near future
2 = 0.1–0.49—needs improvement, but partially workable

3 = 0.5–0.74—reasonably stable but incomplete
4 = 0.75–0.9—stable, moderately complete
5 = >0.9—stable, largely complete

(C) Availability of geographically-referenced presence (and absence where possible) data is essential for assessment. This was done using the expert knowledge of the IUCN/SSC Invertebrate Conservation Sub-Committee. Such spatial expert knowledge by consensus (the approach taken here) has been shown to be remarkably close to that obtained from actual databases (Maddock and Samways 2000). Such information is important because when it is lacking, most taxa are likely to be assessed as data deficient (DD) which limits the usefulness of the Red List.

1 = few records for most species, with little reliable range data
2 = range data for at least some species
3 = range data for around half of known species
4 = range data for most species
5 = range data for almost all species

(D) Availability of taxonomic expertise is also essential for assessment which cannot be made without specialists willing to volunteer their expertise. These specialists are not necessarily restricted to being taxonomists, for example they may be ecologists with taxonomic expertise, however for the vast majority of invertebrate taxa they are taxonomists, often citizen scientists. Taxonomic expertise was assessed using an index based on the number of described species per group and the number of active researchers for that group. The latter was derived from the number of authors of papers from the Web of Science for 2000–2012 (http://wcs.webofknowledge.com). This excluded only occasional publications (restricted to authors of at least 10 papers) and papers on genetic model organisms. This ratio of number of experts to number of species avoids qualitative assessments but does not assume that all experts would be willing to contribute to Red Listing.

1 = experts/species <0.0001 (very little expertise)
2 = 0.0001–0.0009
3 = 0.001–0.009
4 = 0.01–0.09
5 = $\geq$0.1 (strong expertise available)

Functional importance in terms of value for human land use and bioindication

Red List assessments provide valuable data on the status of all taxa assessed. This has obvious conservation value but also provides data on the status of important systems and processes. These may be linked with the Red List of Ecosystems currently under development. These were categorised into three services: established (usually managed) agricultural service providers (pollinators, biocontrol agents); soil health (decomposers, burrowers); and bioindicators of habitat quality, whether in terms of deterioration or improvement through restoration. Taxa were considered (using the expert knowledge of the IUCN/SSC Invertebrate Conservation Sub-Committee) to be important for these services if at least some species play a major role in the function of the relevant ecosystem.

(E) Agricultural service providers (e.g. pollinators, biocontrol agents)

1 = few species with any identified value
2 = some providing some service
3 = many providing some service
4 = some providing some service, with a few of major positive agricultural significance
5 = many providing some service, with many of major positive agricultural significance

(F) Soil organisms

1 = small contribution to leaf litter breakdown and soil formation
2 = some species of importance to leaf litter breakdown and soil formation
3 = many of importance to leaf litter breakdown and soil formation
4 = many important recyclers of nutrients and with high biomass
5 = several of major importance for recycling of nutrients and with high biomass

(G) Habitat quality indicators

Several taxa are well known as important indicators both positively, i.e. when they indicate system health or naturalness (e.g. in freshwater—Ephemeroptera, Plecoptera and Trichoptera), or negatively, when they indicate declining ecological integrity (e.g. chironomid flies—Rosenberg and Resh 1993). More recently, dragonflies have been shown to be excellent surrogates for benthic macroinvertebrates generally (Smith et al. 2007; Simaika and Samways 2009, 2011) and in assessing restoration success (Samways and Sharratt 2010; Samways et al. 2011). The use of terrestrial bioindicators was reviewed and several groups found to be useful in specific ceircumstances (Gerlach et al. 2013).

1 = few species with any identified value
2 = some of importance
3 = many of some importance
4 = some of major importance
5 = several of major importance

Table 2 Priority taxa (phyla)—top 5 priorities coded (in decreasing priority) dark grey (score >20), mid grey (score 20), light grey (score 16–19)

Phylum	Taxon list	Species	Practicality							Flagships	'Needs updating' in RL	Estimated DD	Score
			A	B	C	D	E	F	G	H			
Porifera	N	150	5	3	1	3	0	0	2	0	0	>25	14
Cnidaria	N	100	5	3	1	5	0	0	0	0	0	>50	14
Myxozoa	Y	4	5	4	1	5	0	0	0	0	0	>50	15
Platyhelminthes	N	7,500	4	2	1	3	0	0	0	0	1	>50	10
Micrognathozoa	Y	1	5	4	1	5	0	0	0	0	0	>25	15
Entoprocta	Y	2	5	3	1	5	0	0	1	0	0	>25	15
Nemertina	Y	27	5	4	1	5	0	0	0	0	6	<25	15
Rotifera	Y	2,300	3	3	1	4	0	0	1	0	0	>50	12
Acanthocephala	N	1,150	4	2	1	4	0	0	0	0	0	>50	11
Annelida	N	10,650	4	3	1	3	2	5	0	0	8	>25	18
Mollusca	N	36,000	4	3	3	3	2	3	2	2	1,350	>25	24
Bryozoa	N	50	5	2	1	5	0	0	2	0	0	>50	12
Gastrotricha	N	300	4	3	1	4	0	0	0	0	0	>25	10
Nematoda	N	12,000	4	1	1	3	3	3	0	0	0	>50	15
Nematomorpha	N	230	4	2	1	4	0	0	0	0	0	>50	11
Tardigrada	N	800	4	2	1	4	0	0	0	0	0	>25	10
Onychophora	Y	187	4	3	3	4	0	0	0	5	7	<25	19
Arthropoda	(Y)	1,203,951	5	2	2	4	2	2	2	3	1,076	>50	22

A = species numbers, B = quality of taxonomy, C = availability of geographic data, D = availability of taxonomic expertise, E = agricultural service providers, F = soil organisms, G = freshwater quality indicators

Perceived flagship value for invertebrate conservation in general

The potential of the group to act as a flagship for conservation, to encourage further assessments, and to stand in for other less charismatic groups is a highly relevant consideration. While this inevitably introduces a bias towards charismatic species, a flagship role would make organisation and funding of further assessments and invertebrate conservation more practical. No objective study has been undertaken to identify the criteria for identifying flagships in general. However, Kellert's (1993) pioneering study used attractiveness and symbolic appeal as one category which encourages attention and galvanizes conservation action. This is further supported by Horwitz et al. (1999) and Lemelin (2012), and also by membership numbers of societies: Butterfly Conservation (UK) (18,000), British Dragonfly Society (1,600), The Balfour–Browne Club (water beetles) (300 in 37 countries), whereas there is no booklice society. Quantitative assessments of indicators, including for their flagship significance, when selecting priority areas for biodiversity representation are possible (Lemelin 2012; Manne and Williams 2003; Williams et al. 2000, 2006), but here the suitability of a group to act as flagships was based on perception of existing public interest in the group.

1 = few species of public interest
2 = some of public interest
3 = many of public interest
4 = some charismatic species
5 = many charismatic species

To create a list of priorities, each taxon's score for the above criteria was summed. A reduced weighting (50 %) for the subjective services criteria ("Functional importance in terms of value for human land use and bioindication" and "Perceived flagship value for invertebrate conservation in general" sections) was tested, but this did not significantly affect results and is not included here.

Results

The prioritisation results are shown in Table 2. Comparison of phyla identifies the top priorities as non-marine Mollusca, Arthropoda, Annelida and Onychophora. As some of the phyla are too speciose for comprehensive assessments, the most species rich phyla were allocated to classes, each of which are considered individually below (and shown in Table 3).

'Platyhelminthes'

These all receive low rank due primarily to unreliable taxonomy (the phylum itself is polyphyletic but used here for convenience), lack of expertise and lack of data on status or ecological significance. However, although we do not recommend a complete group assessment, there may well be certain species associated with specific ecosystems or hosts that could be given special focus.

Nematoda

No attempt was made to subdivide the highly diverse Nematoda, as it was apparent that this phylum has a particularly low level of taxonomic completeness and an almost complete absence of distributional data. Nevertheless, progress in taxonomy is being made with certain geographical areas and taxa, and the initiation of Red Listing for subgroups of nematodes is currently being investigated.

Annelida

Annelida were identified as a priority phylum. Terrestrial and freshwater annelids comprise leeches (Hirudinoidea) and earthworms (Oligochaeta). Of the two, earthworms are a clear, high priority, despite difficulties with taxonomy and expertise. Selected taxa should be prioritised, e.g. giant earthworms (charismatic, ecologically significant, taxonomically relatively stable) and other functionally important earthworms (e.g. the 670 species of lumbricid earthworms). We consider this as a priority, especially as earthworms have not been part of any comprehensive assessment.

Mollusca

Non-marine Mollusca were identified as a priority phylum and both classes scored highly. All gastropod orders have similar scores, making prioritization within Gastropoda difficult. Non-marine molluscs include many extinct and threatened taxa (Lydeard et al. 2004; Cuttelod et al. 2011), hence a comprehensive assessment programme will better define the geographical spread of their loss and further understanding of the resultant ecological consequences. Freshwater bivalves and gastropods are included in the IUCN Global Freshwater Assessment and the SRLI (Seddon et al. 2011). The first comprehensive assessments for selected land-snail superfamilies (Helicoidea, Pupillioidea) were incorporated into the European Red List (Cuttelod et al. 2011); given their wide geographical and ecological range these are potential target families for widening to a global assessment.

Arthropoda

Within arthropods, crustaceans, chelicerates and myriapods are high priorities, but insect species richness obscures many important groups. Each of the four classes is considered separately below.

Chelicerata

Spiders (Araneae) are the highest priority chelicerates. However, this group has many probable DD species and a high proportion of undescribed species. Accordingly, particular families could be identified for rapid assessment, such as the charismatic tarantulas and baboon spiders (Theraphosidae) or the recently extensively studied goblin spiders (Oonopidae). Well-known geographical areas with readily available data may also be targeted, such as the Macaronesian archipelagos. In complement, an SRLI approach could be attempted to cover the group as a whole. All options will be explored through the IUCN/SSC Spider Specialist Group which is currently being formed. Other practical priorities are scorpions, microwhip scorpions,

Table 3 Priority taxa (classes etc. of the most diverse phyla)—top 5 priorities coded (in decreasing priority) dark grey (score >20), mid grey (score 20), light grey (score 16–19)

Phylum	Class	Order	Suborder	Taxon list	Species	Practicality							Flagships	'Needs updating' in RL	Estimated DD	Score
						A	B	C	D	E	F	G	H			
Platyhelminthes	'Turbellaria'				1,500	4	2	1	3	?	0	0	0	1	>50	10
	'Monogenea'				1,000	4	2	1	5	?	0	0	0	0	>50	12
	'Trematoda'				5,000	3	2	1	4	3	0	0	0	0	>50	13
	'Cestoda'				1,000	4	2	1	4	3	0	0	0	0	>50	14
Annelida	Hirudinoidea				574	4	2	1	1	0	0	0	0	1	>25	12
	Oligochaeta				10,000	4	3	1	3	4	5	0	0	7	>50	20
Mollusca	Bivalvia				1,050	4	3	4	4	1	0	4	2	119	<25	22
	Gastropoda				35,000	4	2	3	3	2	4	4	2	1,191	>25	24
Nematoda					12,000	4	1	1	3	3	3	0	0	0	>50	15
Arthropoda	Chelicerata			(Y)	112,427	5	2	3	2	3	0	5	5	18	>50	17
		Scorpiones		Y	1,988	3	3	2	3	1	0	1	4	0	>25	17
		Schizomida		Y	267	4	3	2	1	1	0	1	1	0	<25	13
		Palpigradi			87	5	4	2	1	1	0	4	1	0	<25	18
		Araneae		Y	44,540	4	2	2	3	5	0	5	3	15	>50	24
		Amblypygi			163	4	4	2	3	1	0	1	1	0	<25	16
		Ricineulei			61	5	3	2	1	1	0	1	1	0	<25	14
		Uropygi			110	5	2	2	1	1	0	1	1	0	<25	13
		Pseudoscorpionida		Y	3,533	3	2	2	3	1	0	1	1	2	>50	13
		Solifuga			1,113	4	2	2	1	1	0	1	1	0	<25	12
		Opilioacariformes		Y	35	5	2	2	1	1	0	1	0	0	<25	12
		Parasitiformes		Y	54,276	4	2	2	3	3	0	1	0	0	>50	15
		Acariformes		Y	44,516	4	2	1	2	1	0	1	0	0	>50	11
		Opiliones			6,400	4	3	2	3	2	0	1	1	1	>25	16
	Crustacea			(Y)	16,806	4	2	1	4	1	1	1	0	295	>50	14
		Branchiopoda	Anostraca		200	4	2	1	4	0	0	0	0	28	>50	11
			others		900	4	2	1	4	0	0	1	0	4	>50	12
		Cladocera			620	4	2	3	4	0	0	1	0	1	>25	14
		Malacostraca	Amphipoda	Y	150	5	3	2	5	0	1	1	0	71	>50	17
			Anaspidacea		70	5	3	1	1	0	0	1	0	4	>50	11
			Decapoda		2,837	3	2	4	4	1	0	3	3	8	>25	20
			Isopoda	Y	6,000	4	1	2	3	0	2	1	0	42	>25	11
			Mictacea		3	5	4	1	1	0	0	1	0	1	>50	12
			Mysidacea		50	5	3	1	4	0	0	1	0	2	>50	14
			Copepoda		2,814	3	2	1	4	0	0	1	0	105	>50	11
			Pentastomida		130	5	2	1	4	0	0	0	0	0	>50	12
		Ostracoda	Ostracoda		2,000	3	2	1	4	0	0	0	2	12	>50	12
		Remipedia	Remipedia		20	5	3	1	5	0	0	0	1	0	>25	15

whip-scorpions and harvestmen. These are either fairly well known taxonomically or, in the case of palpigrads, often restricted to caves, and could be assessed at least regionally.

Crustacea

Decapoda and Branchipoda are the crustacean priority groups. Freshwater crabs, freshwater shrimps, and crayfish are already in the IUCN Freshwater Assessment (Cumberlidge et al. 2009), and Red Listing is currently being sought for the anomuran freshwater crabs. Of moderate priority are freshwater Amphipoda and terrestrial Isopoda, but both have some significant taxonomic challenges. It may be feasible to include them in assessments of certain priority ecosystems (see Vainola et al. 2008; Rodriguez et al. 2010).

Myriapoda

Within the myriapods, millipedes are the top priority, followed by centipedes. The taxonomy of the Pauropoda and Symphyla is poor and status data too sparse for significant Red Listing. The moderate number of species of millipedes lends this group to a taxonomically- or geographically-focused or sampled approach, although a comprehensive assessment is not likely in the near future owing to taxonomic difficulties and sparse expertise. Nevertheless, establishing a Millipede Red List Group as a first step in developing a full Specialist Group is a priority.

Table 3 continued

Phylum	Class	Order	Suborder	Taxon list	Species	Practicality							Flagships	'Needs updating' in RL	Estimated DD	Score
						A	B	C	D	E	F	G	H			
	Myriapoda			Y	11,999	4	3	3	3	0	2	0	1	1	>50	16
		Symphyla		Y	204	5	2	1	3	1	2	0	0	0	>50	14
		Pauropoda		Y	846	4	1	1	3	1	2	0	0	0	>50	12
		Diplopoda		Y	7,837	4	2	4	3	0	4	2	1	0	<25	20
		Chilopoda		Y	3,112	4	3	3	3	3	0	2	0	1	<50	18
	Hexapoda			(Y)	1,063,533	5	2	2	2	1	1	1	1	603	>50	15
		Collembola			8,163	4	2	1	4	0	3	0	0	0	>50	12
		Protura			816	4	4	1	3	0	1	0	0	0	>25	13
		Diplura			975	4	3	1	1	0	1	0	0	0	>25	10
		Insecta	Archaeognatha		506	4	3	3	1	0	1	0	0	0	>25	12
			Thysanura		554	4	5	3	1	0	1	0	0	0	>50	14
			Ephemeroptera		3,124	3	2	5	4	0	0	4	1	3	>25	19
			Odonata		6,042	4	4	5	3	0	0	4	5	21	>25	25
			Grylloblattodea	Y	32	5	4	5	1	0	0	0	3	1	<25	18
			Dermaptera	Y	1,933	3	4	4	2	0	1	0	0	1	<25	14
			Blattodea	Y	4,641	3	4	3	1	0	1	0	0	0	>25	12
			Isoptera		2,929	3	3	5	4	1	3	0	0	0	<25	19
			Mantodea	Y	2,425	3	4	4	2	0	0	0	1	1	>25	14
			Zoraptera		36	5	5	2	2	0	0	0	0	0	<25	11
			Mantophasmatodea		17	5	4	5	4	0	0	0	4	0	<25	23
			Orthoptera	Y	23,830	4	3	4	3	2	1	2	3	74	<25	22
			Phasmida		3,046	3	4	4	1	0	0	0	5	0	<25	17
			Embiidina		457	4	2	4	1	0	0	0	1	0	<25	12
			Plecoptera	Y	3,713	3	5	4	3	0	3	4	0	4	<25	22
			Psocoptera		3,611	3	2	2	3	1	1	0	0	0	>25	10
			Phthiraptera		5,135	4	3	2	3	0	0	0	0	1	<25	12
			Thysanoptera		5,938	4	3	2	3	0	1	0	0	0	>25	11
			Hemiptera	(Y)	102,183	4	2	2	3	2	1	0	1	5	>50	15
			Neuropterida	Y	6,011	4	4	2	2	0	0	0	1	0	<25	13
			Coleoptera	(Y)	389,487	5	2	3	3	3	2	2	2	68	>50	22
			Strepsiptera		613	4	2	2	3	0	0	0	0	0	<25	11
			Diptera	Y	156,774	5	3	2	3	3	1	2	1	7	>50	20
			Mecoptera		400	4	3	3	4	0	0	0	1	0	<25	15
			Siphonaptera	Y	2,084	3	5	4	3	0	0	0	0	0	<25	15
			Trichoptera		14,548	4	4	4	3	0	3	4	0	4	<25	22
			Lepidoptera	Y	158,423	5	2	2	3	2	1	0	5	265	>25	20
			Hymenoptera	(Y)	153,088	5	2	2	3	4	1	2	1	151	>50	20

Hexapoda

Within the insects, the dragonflies and damselflies (Odonata), heelwalkers (Mantophasmatodea), stoneflies (Plecoptera), caddisflies (Trichoptera), grasshoppers and crickets (Orthoptera), beetles (Coleoptera), moths and butterflies (Lepidoptera) and flies (Diptera) are the top priorities. Other high priorities include mayflies (Ephemeroptera), termites (Isoptera), ice-crawlers (Grylloblattodea), and ants, bees and wasps (Hymenoptera) and phasmids (Phasmida).

The dragonflies and damselflies are being comprehensively assessed, including a global SRLI, by the IUCN/SSC Dragonfly Specialist Group. The relatively newly discovered heelwalkers of southern Africa number only a few species and are being fairly intensively researched in view of their phylogenetic curiosity. Stoneflies, caddisflies and mayflies are all well known as important taxa in freshwater monitoring programs, and are amenable to comprehensive or sampling assessment. Orthoptera are covered by the IUCN/SSC Grasshopper Specialist Group which has started the process of increasing the number of assessments of European Orthoptera and South African bush-crickets.

The hyper-speciose Coleoptera, Diptera, Lepidoptera and Hymenoptera, pose special challenges. Flies in general are relatively poorly known, especially in lower latitudes. Comprehensive assessments are only feasible for taxa in certain areas e.g. Europe or temperate North America, or for certain taxa, such as the ecologically and agriculturally important hoverflies (Syrphidae) which are also fairly well known taxonomically. Coleoptera are particularly challenging in view of the huge number (360,000) of species. There is an existing Red List Authority (RLAs) for European saproxylic beetles (a functional/thematic approach) and the possibilities of listing additional beetle taxa are being investigated, such as the Carabidae sensu lato (tiger and ground beetles), Lucanidae (stag beetles) and Buprestidae (jewel beetles), which have among them many ecologically significant and charismatic species.

For Lepidoptera, butterflies have already been prioritised and have their own IUCN/SSC Butterfly Specialist Group. Another priority, in view of their charisma and pollinator potential are the hawkmoths (Sphingidae). The only systematic Red Listing of any hymenopteran group is for the bumblebees, by the recently-formed IUCN/SSC Bumblebee Specialist Group. Bumblebees are highly charismatic important pollinators with relatively few species, but substantial problems from their enormous variability are only just beginning to be solved with molecular techniques. They are in the process of a global assessment, but this covers only a small part of the diversity (species and ecological) of the Hymenoptera. Further investigation of other families is needed, especially as they include many important pollinators (Exeler et al. 2009). The issue is mostly around taxonomy. The other subgroup of Hymenoptera of major ecological significance and fairly good taxonomic resolution are the ants, and we highly recommend the formation of an IUCN/SSC Ant Specialist Group.

Termites (Isoptera), while of major ecological significance and highly susceptible to landscape change, are fraught with taxonomic challenges, suggesting that some localised studies may well be warranted, especially in tropical areas such as southeast Asia where land changes and deforestation are significant. Other groups, such as Phasmida, are not only difficult to sample comprehensively but also poorly known taxonomically and therefore of lesser priority.

Discussion

Currently, the Red List includes 13,376 non-marine invertebrates, representing only 0.4 % of described species. This can make comparisons between taxa difficult (Stuart et al. 2010) and limits the value of the Red List in terms to biodiversity assessment and conservation. The utility of invertebrate data on the Red List is further compromised by the 6 % of assessments that are out of date, many of which pre-date the current assessment procedure and should not be used in any comparisons.

To overcome these limitations, it is proposed that existing out-dated assessments be re-assessed, and that the number of invertebrate assessments be expanded considerably. The BoL calls for Red Listing of 45,344 invertebrate species (Stuart et al. 2010). This does not distinguish between marine, freshwater and terrestrial invertebrates. Given the wide disparity between marine and non-marine ecosystems, and the great range of taxa represented in them, we recommend that the number of invertebrates in the BoL should be apportioned approximately equally between marine and non-marine taxa. This would require the assessment of 22,672 non-marine invertebrates (the addition of 9,296 more species). An undertaking on this scale would be a major challenge, made more difficult with the urgent need for a meaningful BoL. Fortunately some of the major priorities have bene apparent for a long time and this has led to the creation of some invertebrate Specialist Groups that encompass at least portions of the taxa identified here as priorities. For other taxa new Specialist Groups may need to be developed. Even with Specialist Groups in place, in order to achieve the scale of Red Listing needed, new approaches to assessment may need to be developed to streamline and speed-up the assessment process. Proposal of new approaches lies outside the scope of the present paper, here we seek to propose the priority group that should be assessed in order to make the BoL useable.

It is proposed that major assessment initiatives incorporate the 25 major non-marine invertebrate taxonomic groupings identified here as priorities (Table 3) and equivalent priorities in the marine realm. These high priorities are defined as taxonomic groups, but cover freshwater and terrestrial (from forests to deserts) groups, from temperate zones and tropics. The identification of priorities does not mean that non-prioritised groups should be overlooked. Rather, it is essential that the priorities be added to the Red List and that as many assessments from a diverse taxonomic range should be encouraged as motivated expertise to undertake Red Listing becomes available.

There would also be the possibility to assess species from specific ecological, taxonomic or geographical groupings where appropriate data on a certain set of species are available. In the case of the European assessment process, c. 70 % of land snail species have been assessed in families selected on the basis of their presence in a wide range of habitats throughout the region, as well as those with fewer taxonomic issues. However, as a result, slug families were not assessed owing to taxonomy instability, despite the presence of several endemic taxa that are likely to be highly threatened (Cuttelod et al. 2011). Although it will be ambitious to increase representation of the most species-rich insects, it will certainly be possible to start with sub-groups, which are either known as valuable bioindicators (e.g. carabid beetles, wild bees) or those, which have high flagship potential (e.g. tiger beetles, bumblebees, swallowtail butterflies). As far as practical assessments of subsets of the priority taxa should cover as wide a geographical and ecotypic range as possible, where possible using functionally representative groups as indicators of

Table 4 Summary of all priority groups

			Score	% on RL	Current Red Listing[a]	Complete (C) vs sample (S) or needs lower level prioritization (<)
Annelida	Oligochaeta		20	<1		<
Mollusca	Bivalvia		22	30	FW	C
	Gastropoda		24	7	SG	C (freshwater) < (terrestrial)
Onychophora			19	7	A	C
Arthropoda	Chelicerata	Scorpiones	17	0	SG	S
		Palpigradi	18	0	SG	C
		Amlypygi	16	0	SG	C
		Araneae	24	<1	SG	< + S
		Opiliones	16	<1	SG	S
	Crustacea	Decapoda	20	10	FW	C
		Amphipoda	17	47		C
	Myriapoda	Diplopoda	20	<1		S
		Chilopoda	18	<1	A	<
	Insecta	Ephemeroptera	19	<1		C
		Odonata	25	47	SG	C
		Grylloblattodea	18	4		C
		Isoptera	19	0		C
		Mantophasmatodea	23	0		C
		Orthoptera	20	<1	SG	<
		Phasmida	17	<1		S
		Plecoptera	22	<1		C
		Coleoptera	22	<1	a	<
		Diptera	20	<1		<
		Trichoptera	22	<1		S
		Lepidoptera	20	<1	sg	<
		Hymenoptera	20	<1	sg	<

Top priorities marked in dark grey

FW freshwater assessment, *SG* specialist group, sg: specialist group for part of the taxon, A: Red List group

[a] Red List group for part of the taxon

biodiversity (Gerlach et al. 2013). Specification of each sub-group should be done by the experts for the higher taxonomic groups, and is also a matter of feasibility which we strongly recommend goes hand in hand with importance as prioritised here (Table 4).

Target 1 of the Convention on Biological Diversity Strategic Plan 2011–2020 and the Aichi Biodiversity Target 12 aim to prevent extinction of known threatened species and improve their status. The bias currently present in the Red List is likely to weaken the wider conservation value of steps taken to achieve this. By the time of the next review of this target (2020), a more representative Red List needs to have been created. This is a major challenge and is unlikely to be practical with current procedures. The process of Red Listing needs streamlining to make assessment easier and faster. In addition, assessment needs to focus on priority taxa. To achieve this, we propose a 6 year time frame for implementation of the strategy for creating a more robust Red List, achieving assessment of the priorities through (Table 4):

Comprehensive assessment—the three groups already being assessed: freshwater Mollusca (c. 5,800 extant species/3,331 already assessed), Decapoda (3,073/2,999), Odonata (5,680/2,752); then Onychophora (165/11), Amphipoda (150/71), Amblypygi (136/0), Palpigradi (80/0) Grylloblattodea (27/1), Mantophasmatodea (7/0)

Sampled assessment—Opiliones (6,400/1), Diplopoda (7,500/31), Trichoptera (12,627/4)

Thematic assessment (functional, geographical or ecosystem, which could be combined with a sampled approach) within the following and in rough order—Orthoptera (25,718/236), Oligochaeta (±10,000/9), Lepidoptera (174,250/722), terrestrial Gastropoda (35,000/5,032), Araneae (44,540/32), Isoptera (2,800/4), Coleoptera (360,000/527), Diptera (152,956/7), Hymenoptera (115,000/302), Ephemeroptera (3,046/3), Scorpiones (1,456/0), Plecoptera (3,706/4), Phasmida (3,033/8), Chilopoda (3,149/1).

Although concerns have been raised regarding applicability of Red List criteria to invertebrates (Cardoso et al. 2011a, but see Collen et al. 2012), current experience of Red Listing of non-marine molluscs, Lepidoptera, saproxylic beetles, dragonflies and crabs has shown that it is feasible, as long as it is recognised that only some criteria (principally habitat and geographic range data) are in fact applicable, with most criteria being inapplicable to many taxa, and hence have to be disregarded for most invertebrate assessments. More challenging are issues of species numbers, time required, availability of expertise and funding, and for the BoL to be a monitoring tool, the initial Red List assessment for a taxon is a first stage, with necessity for repeat assessment over time. Reassessment is a difficult issue for all Red Listing, how this may be achieved using new locality data and without detracting resources away from the need for original assessments is the subject of other work, outside the scope of the present paper. The most efficient approach may be to extend the SRLI approach to more invertebrate taxa, especially megadiverse groups, while at the same time adding certain small but phylogenetically curious taxa (e.g. heelwalkers, velvet worms and giant earthworms), as well as certain thematic taxa (e.g. dung beetles, pollinators). A further grouping for consideration are groups of taxa in special habitats, such as invertebrates in caves, and a Cave Invertebrate SG has been formed to address this.

The prioritization described here represents a first stage for determining overall trends in status of a variety of invertebrates, while reducing the large number of DD species which are spread across all taxa. Bland et al. (2012) concluded that DD taxa should be given high priority to determine their conservation status. However, this would probably mean giving high priority to the vast majority of species (as these are necessarily DD at present, if evaluated in view of current knowledge), which is a contradiction in itself. Besides, giving these species a high priority probably is a moot point in most cases if not accompanied by efforts in other areas. We therefore advocate that a strong effort should be made in different areas that could benefit the rapid and correct listing of priority taxa. These priorities include, among others, conducting extensive standardised sampling programs of delimited areas and creating best procedures for species distribution modelling (Cardoso et al. 2011b). Focusing on these different approaches would make the BoL genuinely useful.

The general inverse correlation between species diversity and data quality is particularly apparent for invertebrates (Cardoso et al. 2011b) and in tropical regions where it is further compounded by suspected elevated extinction rates (Vamosi and Vamosi 2008). Reliable assessment of the threat status of invertebrates generally, and hence creation of a meaningful BoL, will depend to a large extent on our ability to resolve the problems of the paucity of good taxonomic and status data.

Although the process of broadening Red List coverage has already started, this has not been done in a strategic way, but purely on the basis of ease of assessment and individual conservationists, Red List partners or funding organisation interests. Furthermore, the process is currently slow due to the effort and time involved in completing large numbers of assessments. This issue could be resolved to some extent through integrating global and national Red Listing efforts, however there are considerable technical and diplomatic issues that currently make this impossible. This again suggests that a more strategic approach might be the best way forward. With the new commitments of many countries to biodiversity conservation formulated in the Aichi Biodiversity Targets and expressed in the foundation of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services there is suggestion that these challenges may become manageable in the near future.

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