Toward reassessing data-deficient species

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Abstract

One in six species (13,465 spp.) on the IUCN Red List are currently classified as Data Deficient due to lack of information on their taxonomy, population status or impact of threats. Despite the chance that many are at high risk of extinction, Data Deficient species are typically excluded from global and local conservation priorities as well as funding schemes. The number of Data Deficient species will greatly increase as the Red List becomes more inclusive of poorly known and speciose groups. A strategic approach is urgently needed to enhance the conservation value of Data Deficient assessments. To develop this, we reviewed 2,879 Data Deficient assessments in six animal groups and identified eight main justifications for assigning Data Deficient status (type series, few records, old records, uncertain provenance, uncertain population status and/or distribution, uncertain threats, taxonomic uncertainty, new species). Assigning a consistent set of justification tags to species classified as Data Deficient is a simple way to achieve more strategic assessments. Such tags will: clarify the causes of data deficiency; facilitate the prediction of extinction risk; facilitate comparisons of data deficiency among taxonomic groups; and help prioritize species for re-assessment. With renewed efforts, it could be straightforward to prevent thousands of Data Deficient species slipping unnoticed towards extinction.

Introduction

Limited knowledge of the biological world is a considerable obstacle to the development of effective conservation measures (Whittaker et al. 2005). Documenting species' distributions, population status and ecology is fundamental to evaluating risks to biodiversity, so information limitations can cause significant gaps in threatened species lists. One in six species assessed on the IUCN Red List of Threatened Species (RLTS) are currently classified as Data Deficient (IUCN 2016). Assignment of the Data Deficient (DD) category does not correspond to a level of extinction risk, but reflects "inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status" (IUCN 2001). The number of DD species on the RLTS has been steadily rising over the last 20 years (Fig. 1), mostly due to the expansion of the RLTS towards neglected taxa such as plants and invertebrates (Collen et al. 2009). The RLTS aims to assess 160,000 species at a cost of $60 million to create a more taxonomically representative Barometer of Life (Stuart et al. 2010). The current overall proportion of DD species (~16%) suggests that should this target be achieved, around 26,000 of these species would be assessed as DD. However, recent assessments of poorly known groups (e.g. odonates: 35% DD) suggest the final figure could be much higher; around 42,000 new DD species added to the Barometer of Life.

Further increases in the number of DD species pose considerable issues for conservation monitoring and prioritization. Data Deficient species can contribute to high uncertainty in estimates of levels of extinction risk across groups due to their unknown risk status (Bland et al. 2012; Hoffmann et al. 2010). This uncertainty not only affects the monitoring of progress towards global biodiversity targets (e.g. Convention on Biological Diversity Aichi targets) but also the setting of new conservation priorities (Trindade-Filho et al. 2012). Global conservation priorities relying on knowledge of threatened species – such as Key Biodiversity Areas, biodiversity hotspots, and many others (Brooks et al. 2006) – do not explicitly incorporate DD species, and they are excluded from metrics of change such as the Red List Index (Butchart et al. 2004) . Species listed as DD are typically not included in national recovery plans, conservation legislation and conservation planning (Sousa-Baena et al. 2013; Walsh et al. 2013).

The IUCN recommendation to afford DD species the same level of attention as threatened species (IUCN 2001) is rarely followed due to the limited funds available for conservation, the very large number of DD species (13,465; IUCN 2016), and the fear they may not be threatened and therefore a poor conservation investment. Conservation investment schemes relying on threatened species listing offer limited funds for DD species, e.g. in 2013 fewer than 1% of the awards from the People's Trust for Endangered Species (PTES 2013), 3% of the awards from the Mohamed Bin Zayed Species Conservation Fund (MBZSC 2013), and only one project of the World Association of Zoos and Aquaria (WAZA 2013) exclusively focus on DD species. Species classified as DD are offered very little protection and funding due to their uncertain conservation status. The IUCN therefore discourages the liberal use of the DD category (IUCN 2001), and states that "assessors should […] place taxa into the Data Deficient category only when there is really no alternative" (IUCN Standards and Petitions Subcommittee, 2016).

Due to the time constraints faced by the many volunteers that undertake red list assessments, greater effort is expended on documenting assessments for data-sufficient species. Understandably, this leads to catch-all justifications such as "listed as Data Deficient as very little is known about this species", with no additional information on the type of information lacking or research actions needed. Data Deficient species assessments suffer from considerable semantic uncertainty, making it difficult to address data gaps. Given the expected rise in the future number of DD assessments, new assessments should provide the maximum amount of conservation-relevant information. We make the case that better consideration of the causes of data deficiency and necessary research actions will improve the utility of DD assessments. We argue that consistent tagging of DD species in a structured manner can help prioritize DD species for re-assessment, and help identify relevant research actions (e.g. taxonomic studies, occupancy surveys and threat surveys), their cost, and likelihood of success. The use of justification tags could be easily incorporated in the assessment process, and would provide a large increase in conservation value with limited extra effort.

Identifying the different justifications for assessing species as Data Deficient

We categorized justifications for the assignment of DD status in six terrestrial and freshwater animal groups. We focused on 2,879 species from six terrestrial and freshwater animal groups that were comprehensively assessed (freshwater crabs: Cumberlidge et al. 2009; crayfish: Richman et al. 2015; mammals: Schipper et al. 2008; amphibians: Stuart et al. 2004) and two that were assessed with the Sampled Red List approach (reptiles: Böhm et al. 2013; odonates: Clausnitzer et al. 2009). Levels of data deficiency varied between 12 and 49% among groups (Table 1). We categorized all DD mammals, reptiles, freshwater crabs, crayfish and odonates, and categorized a randomly selected sample of 600 (38%) DD amphibians (a number similar to mammals, freshwater crabs and dragonflies; Table 1).

Two existing IUCN justifications for DD status (“uncertain provenance” and “uncertain taxonomy”) were infrequently applied: for example, only 23 species of the 628 DD freshwater crabs were assigned either justification. Like the “insufficient information” justification proposed for birds by Butchart & Bird (2010), these tags are unable to capture important detail on the wider range of information deficiencies found in many groups. We therefore assigned species to eight justifications of DD status which capture this variability: uncertain provenance, type series, few records, old records, uncertain population status or distribution, uncertain threats, new species, and taxonomic uncertainty (Table 2). Species listed under "few records" were known from five records or fewer. We categorised "old records" as those collected prior to 1970, a threshold representing more than three generations for most DD species. This date is also comparable with other biodiversity indicators (Butchart et al., 2010). We defined "new species" as species discovered within 10 years of the group assessment. Justifications for listing as DD are not mutually exclusive, so a species may be included under more than one justification (detailed recommendations and examples in Appendix S1). Although we used *post hoc* assignment of justification tags, we recommend that justification tags are assigned during the assessment workshops to capture information discussed orally.

Tags denoting severe uncertainty about a species' natural history (uncertain provenance, type series, few records, and old records) were the most frequently applied for listing as DD in freshwater crabs (92%), dragonflies (83%), amphibians (43%), and mammals (42%) (Fig. 2a). Information was particularly scarce for species of uncertain provenance (e.g. the dragonfly *Oligoaeschna speciosa* is only known from "Darjeeling, North East India"), or species that cannot be matched to wild individuals (e.g. the frog *Hyperolius fuscigula*). Discovery of new species was the most important single factor in amphibians (24%), reflecting recent advances in bioacoustic monitoring, genetics, and inventories in the Neotropics (Köhler et al. 2005).

Continued investment in taxonomy is paramount to keeping the RLTS up-to-date with recent species discoveries (Mace, 2004) and dealing with species tagged as DD due to taxonomic uncertainty. This is particularly marked in some well-known clades (15% of DD mammals and birds; Butchart & Bird, 2010), due to taxonomic disputes on splitting and lumping. In comparison, taxonomic uncertainty justified only 2% of freshwater crab DD classifications, likely reflecting the lack of scientific attention given to these speciose invertebrates – it is estimated that only half of the world's freshwater crabs have been described (Cumberlidge 2009).

Unknown population status and distribution was the main single justification for crayfish (44%), mammals (29%), and reptiles (23%). Large percentages of crayfish (37%) and reptiles (18%) justifications invoked unknown threats. Only in crayfish, a relatively species-poor clade whose centres of diversity are located in developed countries (USA and Australia) did lack of information on population trends and threats justify most DD listings. Although the lack of information on threats and their impact has often been highlighted (e.g. Murray *et al.*, 2014), our study suggests that lack of basic natural history information is the main limiting factor in conducting data sufficient RLTS assessments. Our findings highlight the importance of both taxonomic and fundamental ecological information, and the need for renewed investment in taxonomy and field inventories.

Impact of assessment justifications on predictions of extinction risk

Predictive models of extinction risk are becoming important tools for estimating the likely status of DD species (Bland et al. 2015a). Models based on contextual information (e.g. biology, phylogeny, environment, threats) are calibrated on species of known conservation status, and then applied to DD species to predict their status. Whilst these models provide broad insights into the likely levels of risk faced by DD species, their results should be interpreted in the context of assessment justifications. Using a published model of extinction risk for 493 DD mammals (Bland et al. 2015a), we investigated the differences in predicted extinction risk for subsets of mammals tagged with each of our eight DD justifications (Fig. 2b). The full model predicts 64% of DD mammals to be at risk of extinction but this proportion varies between 25% and 97% among the eight justifications. Whilst species listed as DD due to unknown population trends or threats show similarly low predicted levels of extinction risk, species listed under old records, few records, and in particular type series, show very high levels of predicted extinction risk (Fig. 2b).

These predictions may reflect genuine differences in risk or reflect uncertainty in contextual data. Range size could be underestimated for species known from type series or few records, but information on sampling effort could be used to infer whether a species' range is genuinely small or under-sampled (Good et al. 2006). Whilst the effect of uncertainty in range maps (Bland et al. 2015b) and missing life-history data (González-Suárez et al. 2012) have been investigated in models of extinction risk, systematic accounting of uncertainty remains rare. Information on the causes of data deficiency could be used to fully take into account uncertainty in contextual data, or at least pinpoint species for which predictions are most uncertain.

Recent re-assessment of DD species can shed light on the accuracy of extinction risk predictions according to different causes of data deficiency. For example, 10 DD species included in the extinction risk model have been re-assessed since the 2008 Global Mammal Assessment, including four lemurs previously listed as DD due to taxonomic uncertainty (Schwitzer et al. 2014). The newly assigned conservation status was correctly predicted by the model for all species (Table S1). Validating extinction risk models will require more re-assessment information, in particular for species listed as DD due to reasons other than taxonomic uncertainty. Our proposed justification tags would help refine the accuracy and utility of extinction risk models.

Prioritizing Data Deficient species for research and surveys based on assessment justifications

Transparent prioritization of species for research and re-assessment is desperately needed, as non-threatened DD species tend to be re-assessed first under *ad hoc* surveys (Bland et al. 2015a). These *ad hoc* re-assessments therefore do not inform either of the two stated aims of the IUCN RLTS, which are to monitor biodiversity in a representative manner and identify individual species at high risk of extinction (IUCN 2016). Prioritization protocols can be informed by the likely threat status of DD species, and the cost and likelihood of success of research actions (Joseph et al. 2009; Kearney 2015), all of which are linked to the causes of data deficiency.

Actions required to re-assess a species known from a type specimen collected a hundred years ago will differ greatly to those required to re-assess a relatively well-known species for which information on threats is uncertain. Yet, these two species are not differentiated under the current two IUCN justification tags. Species listed under taxonomic uncertainty are likely to require collection of new specimens, and genetic and morphological comparisons with existing specimens. Species with missing population status or threats information require further field surveys, such as occupancy surveys, abundance or community-based threat assessments. For example, targeted studies into the distribution, ecology and behavior of the Malaysian sun bear (*Helarctos malayanus*) enabled its re-assessment as Vulnerable in 2008 (Nazeri et al. 2012).

We demonstrate that it is possible to explicitly link our proposed DD justification tags with the IUCN Research Needed classification (Table 2), a scheme that enables assessors to select appropriate research actions such as taxonomic research or monitoring of population trends. Although the IUCN Research Needed classification is no longer required supporting information (IUCN 2012), we argue that this scheme is essential supporting information for re-assessing DD species. There is limited utility in noting that species are too poorly-known to assess extinction risk without indicating which actions would resolve the problem. Selection of DD justification tags could go hand-in-hand with determining necessary research actions during assessment.

DD justification tags can also inform the likelihood of re-assessment success, which will be extremely low for species of unknown provenance and for some species known from type specimens. This includes species which cannot be matched to wild individuals (e.g. *Geophis dunni*; Table 1) and *nomen dubia* (e.g. species for which holotypes may have been lost). Some *nomen dubia* species (e.g. the amphibians *Fejervarya altilabris*, *F. assimilis*, *F. brama*, and *F. frithi*) have recently been removed from the IUCN Red List due to their doubtful taxonomic validity (C. Hilton-Taylor; *pers. comm.*). The likelihood of re-assessment success may also be low for species listed under old records, especially in well-surveyed areas (Good et al. 2006). In contrast, recently described and surveyed species may be easier to locate and may provide good opportunities for re-assessment. Information on both successful and unsuccessful surveys can inform estimates of detectability of species, decline in population or range size and, ultimately, re-assessment to data-sufficient categories (Good et al. 2006).

Estimating the likelihood of re-assessment success for DD species is a complex endeavor, reliant on information such as date of last sighting, survey effort, and species detectability (Kearney 2015). Ideally such information would be included in assessments, but may be difficult to compile due to time constraints. We recommend that date since last sighting and details of searches and surveys become recommended supporting information in DD assessments, as these pieces of information are crucial to transparently and cost-effectively prioritizing DD species for field surveys (Kearney 2015). This information is already required supporting information for Critically Endangered (Possibly Extinct) species (IUCN 2012).

Rethinking the application of the Data Deficient category

Butchart & Bird (2010) hypothesized the DD category to be the most misunderstood and controversial on the RLTS, and the most heterogeneously applied among taxonomic groups. We note that many DD species tagged under unknown population status and unknown threats in relatively well-known groups (such as mammals and crayfish) could be assigned to data-sufficient categories if assessors' attitudes were similar to those found in assessors of odonates and freshwater crabs. The most recent IUCN Red List Guidelines (IUCN Standards and Petitions Subcommittee 2016) provide additional information on when to use or not to use the DD category, but further efforts should be made to homogenize DD assessments among taxonomic groups. Consistent tagging of DD species could make taxonomic groups more comparable for reporting and could also minimize semantic uncertainties found in DD assessments. Worryingly, semantic uncertainty can lead to over-estimation of information availability on a species. We tagged many species only under uncertain population, although the lack of information on type series or the age of records suggests that this uncertainty may be the tip of the iceberg. We provide further examples of semantic uncertainty in DD assessments that could be resolved with the application of justification tags (Appendix S1).

We believe our justification tags represent an informative way to classify DD species for scientific purposes, as predictions for extinction risk, necessary surveys, and their likelihood of success clearly differ among the eight tags. We note however that there may be a gap between an optimal solution and a practical one. Given the increasing burden on the volunteers who provide information for RLTS assessments and the large number of DD assessments, alternative documentation standards may be more feasible. The tags "type series", "few records", and "old records" could be combined as "few and/or old records" (Table 2), although species known from type series show distinct extinction risk predictions (Fig. 2b). The "new species" tag may not be necessary if date of description is also accounted for. Overall, the largest differences in survey actions and probability of success are among: "uncertain provenance" (very low probability of survey success); "taxonomic uncertainty" (taxonomic studies need to be undertaken); "few and/ or old records"; and "uncertain population" and "uncertain threats", the latter two tags indicating higher information availability and higher probability of survey success. A second and more applied solution would be to update the Research Actions Needed classification to reflect the different survey needs of DD species, and make this scheme required supporting information for DD species. Which option(s) to implement will depend on the trade-offs between increased understanding of species research and conservation needs, and the time and cost constraints operating on the red listing process (Bland et al. 2015b; Rondinini et al. 2014).

Conclusion

Data Deficient species are potentially of high conservation concern, and will become much more numerous as the RLTS becomes more inclusive of speciose and poorly-known groups (Stuart et al. 2010). We argue that with limited but concerted extra effort, the conservation utility of DD assessments could be substantially increased, thereby helping IUCN achieve the stated aims of the RLTS. By assigning justification tags to each DD species, it is possible to increase the value of DD assessments with minimal time burden on assessors. DD justification tags are needed to identify knowledge deficiencies; predict the likely conservation status of DD species; and identify relevant research and conservation actions. Justification tags also improve the assessment process by limiting semantic uncertainty and inconsistencies among assessors. The use of justification tags and/or recording of Research

Actions Needed would therefore support a more strategic approach to the re-assessment of DD species. Transparently prioritizing DD species for future research is likely to encourage additional funding and protection towards these species, thereby improving our capacity to monitor changes in biodiversity and set effective conservation priorities. But under business as usual, thousands of DD species could slip towards extinction unnoticed.

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Table 1. Levels of data deficiency among animals groups assessed comprehensively or with the Sampled Red List approach.

	Number of assessed species	**Percentage of species classified as Data Deficient**	**Percentage of threatened data-sufficient species**[1]
Mammals	5,282	12.8	24.5
Amphibians	6,260	25.4	41
Reptiles[2]	*1,500*	*21.8*	*18.9*
Freshwater crabs	1,281	49.3	31.1
Crayfish	586	21.1	31.3
Odonates	*1,500*	*35.1*	*13.9*

Table 2. Definition of justification tags for Data Deficient species, with associated Research Needed actions, examples, and alternative tags.

Justification tag	Definition	Recommended Research Actions Needed	Example	Alternative tags
Type series	Species known from one collection event at one locality, from which name-bearing	Research on population size, distribution and trends (1.2); life-history and ecology (1.3);	The frog *Pristimantis salaputium* has not been recorded since its original collection in Cuzco department,	Tags could be grouped as 'few and/or old records'. 'Old

[1] Data-sufficient species are listed as Least Concern, Near Threatened, Vulnerable, Endangered or Critically Endangered. Extinct and Extinct in the Wild species are excluded from calculations.
[2] Groups assessed with the Sampled Red List approach shown in italics.

	specimen(s) have been designated.	harvest, use and livelihoods (1.4); threats (1.5); actions (1.6).	Peru, in 1978.	records' may not be necessary if date since last sighting is collated.
Few records	Species known from five records or fewer.	Research on population size, distribution and trends (1.2); life-history and ecology (1.3); harvest, use and livelihoods (1.4); threats (1.5); actions (1.6).	The coppery pipistrelle *Arielulus cuprosus* is only known from three specimens recorded in Malaysian Borneo, and has not been recorded since 1992.	
Old records	Species known from records collected prior to 1970.	Research on population size, distribution and trends (1.2); life-history and ecology (1.3); harvest, use and livelihoods (1.4); threats (1.5); actions (1.6).	The white-toothed mouse *Coccymys albidens* has only been recorded from two localities during the Archbold Expedition in 1938 in Indonesia.	
Uncertain provenance	Species known from specimens with very uncertain locality information, therefore the species' distribution cannot be mapped.	Research actions unlikely to be feasible	The frog *Scaphiophryne obscura* is known from the non-specific type locality of "Côte N.O. [north-west] de Madagascar", and no distribution map can be prepared for it.	
Taxonomic uncertainty	Species for which uncertainty regarding taxonomy directly leads to paucity of data on distribution, population status, ecology, and threats.	Taxonomy (1.1); possibly other research actions.	The crayfish *Procambarus steigmani* may be synonymous with *P. regalis* which would greatly increase the range of this species; hence the species is assessed as Data Deficient.	
New species	Species described in the last 10 years	Research on population size, distribution and	The dragonfly *Scalmogomphus wenshanensis* was described	Tag may not be necessary if date of

	before the assessment.	trends (1.2); life-history and ecology (1.3); harvest, use and livelihoods (1.4); threats (1.5); actions (1.6).	from single male type and single female paratype collected in 2005 in Yunnan, China.	description is considered.
Uncertain population status and/ or distribution	Species for which information on geographical distribution, population size, and population trends are unavailable or uncertain.	Research on population size, distribution and trends (1.2).	The lizard *Anolis megalopithecus* is listed as Data Deficient because there is a lack of information on its exact distribution, the number of locations at which this species occurs and the population status.	
Uncertain threats	Species for which information on threats (and species response to those) cannot be determined.	Research on threats (1.5).	The habitat of the Ethiopian rodent *Ammodillus imbellis* is being severely degraded by grazing by cattle and goats; however the impact of this threat on the species is unknown. It is not known if the species is present in any protected areas.	

Figure legends

Figure 1. Total number of species assessed (black), listed as threatened (dark grey) and listed as Data Deficient (light grey) on the IUCN Red List of Threatened species (IUCN 2014). Species assessed with version 3.1 of the criteria between 2002 and 2014.

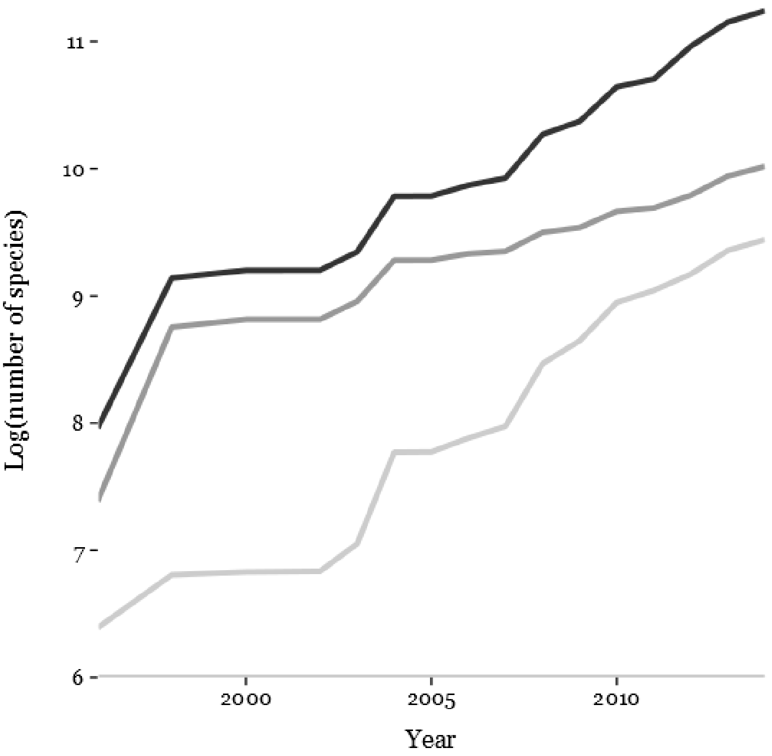
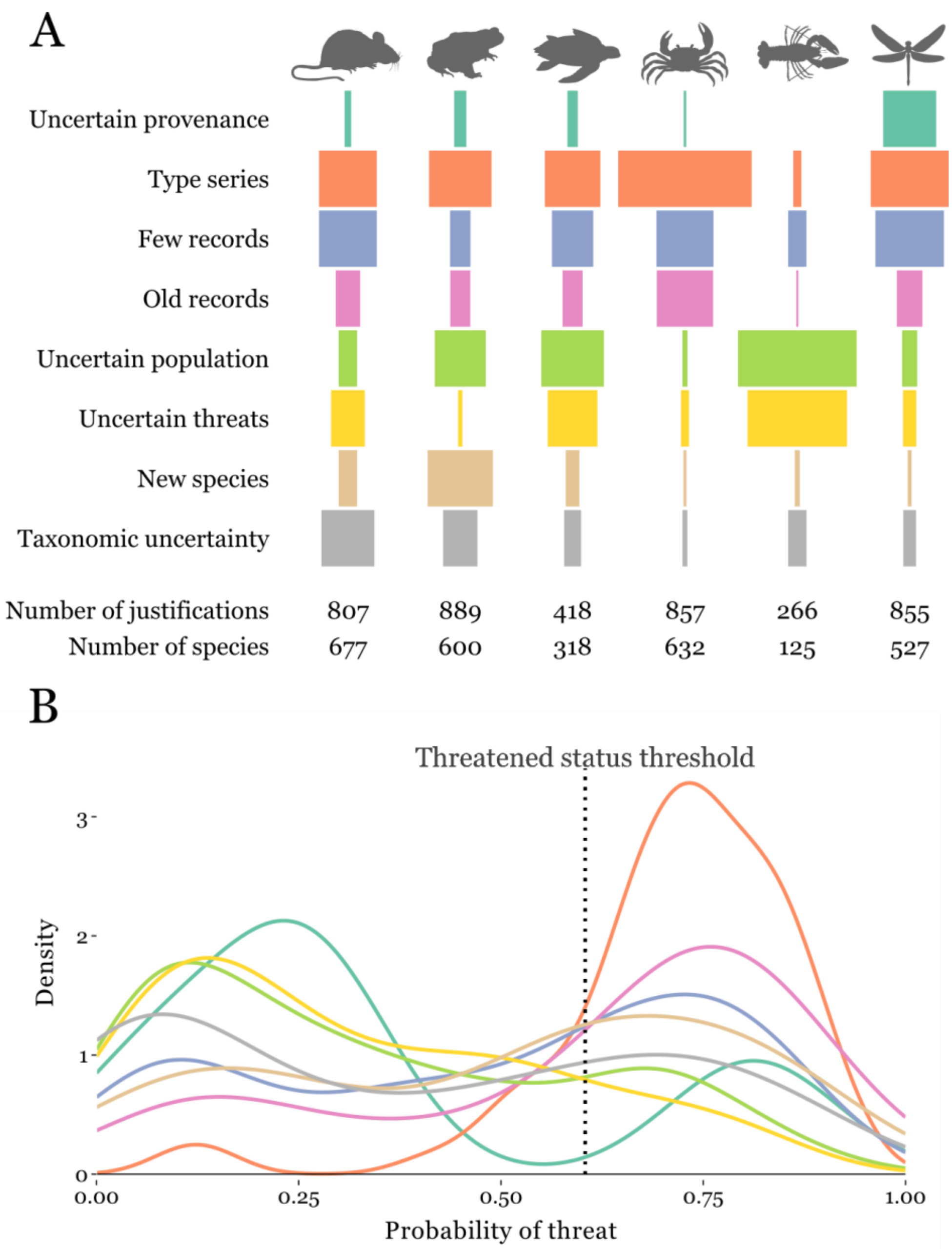


Figure 2. a) Justification categories for all Data Deficient mammals, reptiles, freshwater crabs, crayfish and odonates and a subset (600 of 1,578) of Data Deficient amphibians. Multiple justifications can apply to any one species. See main text and Appendix S1 for further explanations on Data Deficient justifications. b) Distribution of predicted probability of threat for 493 Data Deficient mammal species assigned to each justification tag, using a model calibrated on data-sufficient species and based on life-history, environmental and threat predictors. The threshold shown best classifies data-sufficient species as threatened or unthreatened on the basis of predicted probability of threat. Sample sizes vary for different justifications; see Figure 2a and Appendix S1.


A
Uncertain provenance
Type series
Few records
Old records
Uncertain population
Uncertain threats
New species
Taxonomic uncertainty
Number of justifications
Number of species
807
677
889
600
418
318
857
632
266
125
855
527
B
Threatened status threshold
Density
3
2
1
0
0.00
0.25
0.50
0.75
1.00
Probability of threat