Report

Workshop: Species Vulnerability Traits

22-25 October 2007
Silwood Park, Imperial College, Berkshire, UK

Summary

A four-day Species Vulnerability Traits workshop was hosted jointly by Imperial College London, IUCN Species Programme and IUCN Species Survival Commission (hereafter referred to jointly as IUCN) and the Zoological Society of London. It formed an important early step in two new projects that aim to identify the traits that predispose species to elevated vulnerability to extinction, particularly due to the impacts of climate change.

The workshop was attended by 31 biologists whose expertise spanned a broad range of taxonomic groups and biodiversity-threatening processes. Over the first three days, participants identified, discussed and eventually reached consensus on a list of traits that are generally indicative of species' vulnerability to extinction across all taxonomic groups and due to a range of threats. These will form the basis of a project to update the data collection structures and guidelines for the IUCN Red List.

The last day of the workshop focused specifically on the threat of climate change and was attended by a subgroup of climate change biologists and spatial modelers. From the workshop's overall trait list, participants identified the core set of traits that are most important for assessing species' climate change vulnerability, but also for which data could practically be collected in the IUCN project's short time frame (6 months). Following the workshop, IUCN will refine the list of traits and coordinate the collection of these trait data for selected taxonomic groups including global amphibians, birds and corals.

The workshop was regarded as successful in meeting its aims. As well as generating vital information for the IUCN, it served to inform members of the conservation community of the hosts' plans. The resulting information and strategies will be used to complement the IUCN's Red List categories and criteria to assess species' vulnerability to climate change and other threats, to provide early warning of potential imminent threat to species, as well as to conduct broad scale analyses to advise conservation planning and prioritisation.

Wendy Foden, Species Programme, IUCN (wendy.foden@iucn.org) and **Ben Collen**, Institute of Zoology, Zoological Society of London (ben.collen@ioz.ac.uk).

Workshop aims and background

From the ever-growing IUCN Red List of Threatened Species it is apparent that similar levels of extinction risk are typically clustered within closely related species. These species share many of the same biological attributes, suggesting that certain traits predispose species to an elevated risk of extinction. Trait information, which indicates a species' intrinsic susceptibility to extinction independently of any threats, can provide important additional and complementary information to its Red List threat status.

Two new projects have been established to develop methods for collecting species' trait information. The first, coordinated by the Zoological Society of London (ZSL), focuses on traits associated with vulnerability to all threats. The second, organized by the IUCN, focuses specifically on the traits associated with vulnerability to climate change and includes collecting trait data for pilot taxonomic groups, including amphibians, birds and corals. The projects will produce specific recommendations to IUCN's Biodiversity Assessment Subcommittee (BASC) for modifying existing Red Listing guidelines and protocols, including updates to the IUCN's Red List database.

The Species Vulnerability Traits workshop formed an important early step in the projects' development. By bringing together relevant experts, our aim was to begin the process of identifying traits and developing project methodology, as well as to communicate objectives and plans. More specifically, workshop aims included:

- Identifying the vulnerability traits relevant to various taxonomic groups
- Identifying the vulnerability traits associated with relevant threatening processes, with a particular focus on climate change
- Identifying possible methods of using trait data for species assessments and other conservation purposes
- Guiding the development of a proposal to the IUCN for improvements to the guidelines and data collection structures and tools to enable best collection and use of trait data

Workshop activities

The workshop was attended by 31 biologists representing either specific taxonomic groups or particular threatening processes. A strong focus was also placed on representation of expertise in climate change and spatial modeling. A photograph of participants appears below and their full details are included in Appendix 1.

Attendees of Day 3 of the Species Vulnerability workshop at Silwood Park. From left: (standing) Ana Rodrigues; Rob Alkemade; David Keith; Rob Ewers; Rob Marchant, Stephen Williams; John Bielby; Andy Sheppard; Nick Dulvy (standing centre front); Neil Brummitt; Sarah Holbrook; Ben Collen; Simon Butler; Simon Stewart; Resit Akçakaya; Paul Pearce-Kelly; From left: (sitting) Stu Butchart; Mar Cabeza; Joaquin Hortal; JB Mihoub; Rich Grenyer; Jean-Christophe Vié (sitting centre front); Wendy Foden; Shyama Pagad; Craig Hilton-Taylor; Keith Crandall and Georgina Mace.

The first three days of the workshop involved all participants and focused on the development of a comprehensive and detailed list of the traits associated with vulnerability to extinction. Sessions were dedicated to ensuring that all major threat types were considered and that the constraints and particulars of all major taxonomic groups were taken into account. The fourth day involved a subset of 11 experts on climate change, spatial modeling and/or the planned pilot taxonomic groups who aimed to tailor the previous days' results for use on the IUCN's 'Species Vulnerability to Climate Change' project. A summary of each day's activities and discussions appears in Appendix 2.

Workshop Outcomes

Traits associated with overall vulnerability to extinction

Table 1 contains the comprehensive list of species vulnerability traits developed during the first three days of the workshop. While the majority of traits are associated with vulnerability to multiple threats (e.g. low reproductive rates make species slow to recover from declines and hence more vulnerable to any threat), a few are specific to vulnerability to a particular threat (e.g. dependence on climate-related trigger or cue only relates to threat from climate change).

Table 1: Traits identified by species experts as indicative of vulnerability to extinction due to a range of threats and generally applicable across all taxonomic groups.
** Asterisks indicate groups of traits that should be recorded for each life history stage separately. Fields in blue already exist in the IUCN's SIS Red List database so this data is included in existing data collection protocols and may already have been collected.*

Trait category	Detailed traits
Range characteristics	**1. Range size** 1.1. Extent of occurrence *(value – km²)* 1.2. Area of occupancy *(value – km²)* 1.3. (Maps and spatial characteristics of mapped range) 1.4. Is the species migratory? (yes /no /don't know) *1.5.* Is the species confined to a particular geographical feature? *(island /mountain top /other)* **2. Use of space*** 2.1. Elevation *(max; min)* 2.2. Depth in metres below sea level *(max; min)* 2.3. Depth zone *(shallow photic; deep photic; bathal; abyssal; hadal)* 2.4. Does the species inhabit a linear habitat? *(river /river banks /cliffs /sea shore /nonlinear)* 2.5. What is the species' vertical niche in its habitat? *(tick boxes: canopy /subcanopy /midcanopy /understory /terrestrial /fossorial /semi-aquatic /(need greater range of aquatic depth zones))* 2.6. Fragmentation metric and shape of range from mapping if possible. **3. Habitat *** 3.1. Habitat type(s) *(selected from IUCN classification schemes and possibly a more detailed subset for each; selection between obligate or facultative habitat use)* **4. Microhabitat *** 4.1. Does the species have a specialised habitat and/or microhabitat? *(yes/no/don't know; enter the microhabitat)* 4.2. Is the species physiologically buffered from climate change impact by its microhabitat? *(yes/no/don't know; enter the buffering microhabitat)* **5. Home range size** 5.1. If mobile, what is the species' home range size? *(value)*
Population	**1. Population size** 1.1. Number of mature individuals *(value)* 1.2. Total population size *(min, max)* 1.3. Does the species undergo extreme fluctuations? *(yes /no)* 1.4. Is the species vulnerable to Allee effects? *(yes /no /don't know)* **2. Density** 2.1. What is the average/normal population density in the area occupied by the species? *(e.g individuals per unit area)* **3. Metapopulation dynamics** 3.1. Does the species exist as a metapopulation? (yes /no /don't know) 3.2. What is the size of largest viable subpopulation? *(either values for area or number of individuals)* 3.3. What is the area needed to sustain a minimum viable population *(value or banded ranges)* 3.4. To what degree are the subpopulations connected? *(high /medium /low /don't know)*

Life history	**1. Reproductive rate** 1.1. Generation length *(value)* 1.2. What is the average age of first reproduction *(value)* 1.3. What is the average longevity *(value)* 1.4. What is the species' average reproductive rate? *(number of offspring produced per individual in an appropriate unit of time)* ***2.*** **Life history stages** 2.1. Does the species have multiple life history stages? If so how many life history stages does it have? *(value; text)* 2.2. How many life stages with different habitat/microhabitat requirements does the species have? *(value; text)* **3. Resilience** *3.1.* Has the species become naturalized outside its native range? *(yes /no /don't know)* 3.2. Has translocation been used successfully as a conservation intervention? *(yes /no /don't know)* 3.3. Following disturbance, does the species have a specific strategy for persistence or regeneration? *(yes /no /don't know; text)* 3.4. At which stage of succession would this species establish? *(early /mid /late /don't know)* 3.5. Does the species persist in anthropogenically transformed habitats? (yes /no /don't know)
Breeding system	**1. Reproductive strategy** 1.1. What mode of reproduction does the species use? *(sexual /asexual l/both)* 1.2. Does reproduction happen in a single event per lifetime (semelparity) or on multiple occasions (iteroparity)? *(semelparity /iteroparity /don't know)* 1.3. To what degree is the species monogamous *(high /moderate /not monogamous /don't know)* 1.4. Is the species self incompatible? *(yes /no /don't know)* 1.5. Does the species have internal vs. external fertilization? *(internal /external /don't know)* *1.6.* Do parents provide care to offspring? *(yes /no /don't know)* 1.7. Are individuals bisexual/hermaphroditic? *(yes /no /both bisexual and unisex individuals present)* 1.8. Plants: What is the pollination or fertilisation vector? (wind /water /insect /mammal /bird /other) **2. Sex ratio** 2.1. What is the ratio of breeding females: males? (value:value) 2.2. Is sex environmentally determined? *(yes /no /don't know)* 2.3. Is reproductive success skewed i.e. are some members of one sex prevent others from reproducing? *(yes /no /don't know; ideally obtain measure of proportion of individuals producing offspring)*
Behavioural characteristics	**1. Activity timing** 1.1. Is the species diurnal or nocturnal? *(diurnal /nocturnal /crepuscular (active at dawn and dusk) /cathemeral (active at any time) /don't know)* 1.2. Does the species exhibit seasonal estivation, hibernation, torpor or dormancy? *(tick boxes /don't know)* **2. Congregatory behaviour** 2.1. Does the species need to congregate for reproduction or foraging? 2.2. Is the species solitary outside the breeding season? *(yes /no /don't know)*

Morphological and physiological characteristics	1. **Environmental tolerances*** 1.1. Is there a known environmental tolerance that is likely to be exceeded due to climate change? *(yes /no /don't know)* 1.2. Defining environmental tolerances: 1.2.1. What is the species' temperature range? *(min; max; optimum)* 1.2.2. What is the species' rainfall/moisture range? *(min; max; optimum)* 1.2.3. What is the species' altitudinal range? *(min; max; optimum)* 1.2.4. What is the species' pH range? *(min; max; optimum)* 1.2.5. What is the species' heavy metal tolerance range? *(min; max; optimum)* 1.2.6. What is the species' pollutant tolerance range? *(min; max; optimum)* 1.2.7. What is the species' salinity range? *(min; max; optimum)* 1.2.8. What is the species' fire frequency range? *(min; max; optimum)* 1.2.9. What is the species' flooding frequency range? *(min; max; optimum)* 1.2.10. What is the species' fire frequency range? *(min; max; optimum)* 1.2.11. What is the species' CO_2 tolerance range? (min; max; optimum) 1.2.12. What is the species' O_2 tolerance range? (min; max; optimum) 1.2.13. What is the species' nitrate tolerance range? (min; max; optimum) 1.2.14. What is the species' acid rain/sulphuric acid tolerance range? (min; max; optimum) 1.3. Does the species have a shell or exoskeleton made of aragonite? *(deduce from taxonomy)* 1.4. Is the species endothermic, ectothermic or homeothermic? *(deduce from taxonomy)* 2. **Photosynthetic physiology** 2.1. What type of photosynthesis does the plant use? *(C_3 /C_4 /CAM /don't know; facultative vs. obligate)* 3. **Body size** 3.1. How large is the average adult male? (length /height ; mass; ?) 3.2. How large is the average adult female? (length /height; mass; /?) *3.3.* Plants: how large is the average seed? *(volume /weight)* 4. **Growth form** *4.1.* What is the species' growth form *(for plants: use classification scheme already in SIS; need another system for marine invertebrates)*
Ability to disperse	1. **Dispersal vector*** 1.1. If passively dispersed, what is the dispersal vector? *(wind /water /animals /birds /?humans)(choose any combinations)* 2. **Intrinsic dispersal capacity*** 2.1. What is the species' maximum intrinsic dispersal distance? *(value)* 2.2. What is the species' usual intrinsic dispersal distance (the usual dispersal distance in the short-medium term)? *(value /distance bands: <1km /<10km /<100km /100+km)* 3. **Barriers to dispersal*** 3.1. How likely is it that that the species could disperse to a new range? (no dispersal possible /dispersal possible but unlikely /dispersal very likely) 3.2. Is the opportunity to disperse limited by geographical barriers? *(yes /no /don't know; enter barrier(s))* 3.3. Is the opportunity to disperse limited by anthropogenic barriers *(yes /no /don't know; enter barrier(s))* 3.4. Is the opportunity to disperse limited by habitat movement time lags (i.e. some habitats can move faster than others e.g. saltmarsh cf. rainforest *(yes /no /don't know; please describe)*

Phenology

1. **Phenological cues***
    1.1. Is the species' persistence dependent on a specific environmental trigger that's likely to be disrupted by climate change (at any stage in the species' life history)? *(yes /no /don't know)*

Event stimulated	What is/are the cue(s) (quantify triggers where possible)	When (calendar time/season) do(es) the cue(s) operate?	How sensitive is the species' response *(high /medium /low)* ?
Mating behaviour			
Migration /dispersal			
Spring bud emergence			
Flower emergence			
Life history stage progression			
Egg laying			
Seed germination			
Leaf drop			
Etc.			

2. **Does the species exhibit protandry or protogyny?**

Multi species interactions

1. **Trophic level**
    1.1. What is the species' trophic position? *(top predator /predator /consumer /detritivore /parasite (hemi-vs. sapro- vs. epi- vs. holoparasitic) /primary producer(autotroph))*
2. **Energy acquisition***
    What is/are the species' main energy sources? *(tick boxes: fish /insects /birds /small animals /carrion /fruit /grass /leaves /large animals /molluscs and crustaceans / plankton / etc)*
3. **Dependency on other species***
    3.1. Approximately how many other species is this species dependent on for survival (including hosts, prey & mutualisms)? *(1; 1-4; 5-10; 11+; don't know; if <5 then list where possible)*
    3.2. Is the species known to be dependent on any interspecific interaction that is likely to be disrupted by climate change (including indirectly for example via CO_2 fertilisation)? *(yes /no /don't know; enter interaction details)*

Genetic characteristics

1. **Genetic diversity**
    1.1. Is the taxon known to have gone through a genetic bottle neck in the past or be known to have low genetic diversity? *(yes /no /don't know; give details)*
    1.2. Genetic diversity *(value for all available measures – details to be worked out)*

Exposure to human exploitation

1. **Susceptibility to capture**
    1.1. How conspicuous is the species in its habitat (e.g. bright colours, noisy)? *(high /medium /low)*
    1.2. How valued or desired is this species or its close relatives? *(high /medium /low; description)*
    1.3. Does the species cause danger or damage to humans (either directly or indirectly e.g. as a vector of disease)? *(yes /no /maybe /don't know)*

The greatest challenges in drawing up the list included:

- **Balancing idealism and pragmatism in trait selection.** While a list of information needed for informing vulnerability assessments is relatively easy to develop, the collection of such information for the world's 5-10 million species (May et al 1995) is likely to prove more difficult. While pragmatic participants constantly tailored traits for the use of existing data and the volumes and types of information reasonably requested from species experts, the idealists defended the need for a 'wish list' that would help to focus biologists' attention on collecting this important information, even where it is not currently available. The resulting list lies somewhere between these extremes.

- **Ensuring that the listed traits were not conflated with the threats with which they are associated.** In order to be reliable for testing vulnerability to future threats, the traits should be independent of threats, and be measurable even in the absence of threat, or under changing threat conditions. If a trait is conflated with a threat and this threat changes in an unanticipated way then the trait information may lose its value. For example, if 'vulnerability to climate change' was recorded and current interpretations of regional climate change predictions changed from a 'warming and drying' scenario to one of 'cooling and drying', the recorded information would become worthless. If, however, the traits of 'temperature tolerance range' and 'rainfall tolerance range' had been recorded, the information would continue to be useful.
  Although Table 1 traits in categories 'exposure to human exploitation' and 'susceptibility to capture' are not entirely independent of threat, participants were unable to find equivalent unconflated measures of this important indicator of vulnerability to over harvesting, so it was agreed that these should be included on the list.

- **Reaching a common understanding of the trait definitions**. Traits were often relevant to certain taxonomic groups but not others. In some circumstances, traits could be associated with both high and low vulnerability depending on taxonomic group, threat or simply due to a nonlinear relationship between the trait and the threat. Unraveling these complexities and reaching consensus on interpretation was usually helped (though occasionally made worse) by **defining measurements, terms and questions.** This involved specifying how the question could be asked of experts, supplying the range and types of answers these questions would elicit (shown in italics in Table 1) and specifying how these would relate to the vulnerability assessments. The definition of terms such as 'minimum viable population' and 'metapopulations', however, remained contentious.

- **Defining quantitative vs. qualitative traits.** Finding relevant and appropriate quantitative measures of certain traits, given that such measurements need to apply to all taxonomic groups, was extremely challenging. The alternative of using more qualitative measures (e.g. expert opinion of *high, medium or low* habitat specificity), although allowing seemingly easier data collection, is extremely difficult to interpret consistently. Even with careful guidelines for the use of the terms, such measures are likely to be subjective and inconsistently applied between taxa. Where possible, participants avoided qualitative measurements, but for some traits no universally applicable quantification measure could be identified. More development of these measures in practice will be needed to establish useful and reliable measures.

- **Species with multiple life history stages.** Different stages of many species' life history (e.g. adults, larvae and eggs in insects; adults, pollen and seeds in higher plants) have different and sometimes even non-overlapping microhabitat and ecological requirements. Participants noted that it is very important to record certain traits such as environmental tolerances, microhabitat, phenological cues and interspecies interactions for each life history stage individually. The list of such traits and how this would be accomplished was discussed, though not fully resolved at the workshop.

Traits associated with vulnerability to climate change

The last day of the workshop focused specifically on the threat of climate change and was attended by a subset of participants, namely the climate change biologists, spatial modelers and some taxonomic experts with relevant experience. Using the comprehensive trait list developed during the first three days of the workshop, participants identified the core set of traits that are most important for assessing species' climate change vulnerability. Trait selection was made by choosing the traits most strongly associated with climate change vulnerability, but also considering those for which data could practically be collected in the IUCN project's short time frame (6 months).

Answers to questions in the following four categories of traits were identified as the information that could practically be used to assess global species' vulnerability to climate change. Where answers are not known or cannot be inferred, they should become priorities for research and data collection. The collection of data for the larger set of traits in Table 1 remains a target, but the traits below are the priorities for IUCN's current Climate Change and Species Vulnerability project.

1. DIAGNOSTIC TRAITS

A. **Specialised habitat and/or microhabitat requirements.** Under a changing climate, all species are likely to experience changes in their habitats, including in the species assemblages of communities. Those with general and unspecialized habitat requirements are likely to be able to tolerate a greater level of change, while species with more specialized requirements will be less tolerant and therefore less likely to survive. The vulnerability associated with high habitat specialisation is compounded when a species has **several life stages, each with different specialized habitat or microhabitat requirements.**

B. **Narrow environmental tolerances or thresholds that are likely to be exceeded due to climate change at any stage in the life cycle.** The physical effects of climate change range from changes in precipitation and temperature to altered pH and carbon dioxide levels. The physiology and ecology of many species is tightly coupled to very specific ranges of these parameters and such species are therefore vulnerable to climate change. Even species with broad environmental tolerances and unspecialized habitat requirements, however, may have thresholds beyond which ecological or physiological function quickly breaks down.

C. **Dependence on a specific environmental trigger that's likely to be disrupted by climate change.** Many species rely on environmental triggers or cues for migrating, breeding, egg-laying, seed germination, hibernation, spring emergence and a range of other essential processes. While some cues such as day length and lunar cycles will be unaffected by climate change, others such as rainfall and temperature (including their interacting and cumulative effects) will be heavily impacted upon by climate change. Species become vulnerable to changes in the magnitude and timing of these cues when they lead to an uncoupling with resources or other essential ecological processes e.g. early spring warming causes the emergence of a species before their food sources are available. Climate change vulnerability is compounded when different stages of a species' life history rely on different cues, or where males and females rely on different cues.

D. **Dependence on interspecific interactions which are likely to be disrupted by climate change.** Many species' interactions with prey, hosts or symbionts will be affected by climate change either due to the decline or loss of these resource species from the dependent species' ranges or loss of synchronization in phenology. Species dependent on such climate change sensitive interactions are more vulnerable to extinction, particularly where they have high degree of specialisation for the particular resource species and are unlikely to be able to switch to or substitute other species.

E. **Poor ability to disperse to a new or more suitable range.** In general, the particular set of environmental variables to which each species is adapted (their "bioclimatic envelopes") will shift polewards and to increasing altitudes. Species with poor dispersal ability are unlikely to migrate fast enough to keep up with these shifting climatic envelopes and will therefore become increasingly vulnerable as their habitats become progressively more unsuitable.

   Even when species have the dispersal capacity to reach newly suitable bioclimatic areas, several other factors may affect the success of dispersal. Intrinsic factors that increase species' vulnerability include **poor ability to colonise new areas** and to adapt to the inevitably altered conditions there. Useful indicators for colonisation potential include (where such data exists) information on existing naturalisation outside species' native ranges and whether past translocation efforts have been successful. Extrinsic factors decreasing dispersal success include the **presence of any geographic barriers** such as mountain ranges, oceans or rivers; **anthropogenic transformation of migration route or newly climatically suitable areas**, including due to agriculture, deforestation or urbanization; and any **lag between the dispersal of species and the habitats or resource species on which they depend**.

2. GENERAL VULNERABILITY TRAITS

The impacts of the above traits may be worsened by interactions with the following:

A. **Low reproductive rate.** While weedy, fast reproducing species may quickly recover from extinction events, those with low reproductive rates require longer periods for populations to return to their original sizes. Where extinction events occur too frequently for population sizes to recovery completely, slowly reproducing species face ongoing population declines.
B. **Small population size.** The inherent vulnerability of small populations to Allee effects is compounded by any further extinction events.

C. **Extreme fluctuations** in population sizes result in bottleneck stages during which populations are particularly vulnerable to extinction due to climate change or any other threat.
D. **Long generation times.** Climate change impacts are predicted to happen at a rate that will place severe challenges on the adaptive potential of many species. Those with long generation times will have relatively fewer generations to accumulate the physiological and behavioural traits needed for the species to adapt to a new climate.
E. **Low genetic diversity.** Species with low genetic diversity, often indicated by recent bottle necks in population numbers, potentially face inbreeding depression and generally exhibit lower ranges of phenotypic variation. As a result, such species tend to have fewer novel characteristics that could help them to adapt to the new climatic conditions.

3. BIOCLIMATIC MODEL OUTCOMES

Bioclimatic, demographic and various other species-based models are increasingly being used to assess individual species' extinction risks due to climate change. Unfortunately such approaches are only possible for a relatively small number of data rich taxa, and there is little consistency in model assumptions (e.g. regarding dispersal), the climate change scenarios used, the regional interpretations of global climate change predictions, the statistical methods used to derive predictions and the variables included. Nonetheless, such models provide a useful 'red flag' for conservation and in general, models projecting high extinction risk indicate that such species are very likely to face an elevated extinction risk.

4. METAPOPULATION MODELLING TRAITS

The IUCN is in the process of launching a further project aimed at using fine-scale spatial modeling, combined with demographic and ecological variables, to develop detailed predictions of certain species' climate change responses. Representatives from this project identified the trait data that will be needed to populate these models, and it was agreed that this information should be collected simultaneously with that for the trait-based climate change vulnerability assessment.

In addition to the climate change traits above and a variety of information already collected via the IUCN's Red List Database, the following information was identified as important for the planned detailed spatial and demographic models:

A. What is the area needed to sustain a minimum viable population?
B. If mobile, what is the species' home range size?
C. What is the average population density in the area occupied by the species?

It is important to note that neither the trait-based nor modeling approaches to species assessments is intended to replace traditional Red Listing methods. Where sufficient data exists, assessments using all methods are likely to prove complimentary and extremely useful for better understanding the species' responses, as well as the strengths and weaknesses of each method.

Conclusion

The Species Vulnerability Trait Workshop was regarded as successful in meeting its aims of identifying key species traits associated with elevated extinction risk across taxonomic groups and to a range of threats, particularly climate change. Organisers received valuable guidance on how trait data collection could best be carried out. This will inform proposals to the IUCN's BASC for modifications to the IUCN Red Listing guidelines and data collection methods.

Participants felt that the use of trait information in species assessments will prove useful as a complementary tool to Red Listing and climate change spatial modelling. By bringing a degree of predictive power to species assessments and hence facilitating pre-emptive conservation intervention, it is likely to become a valuable new tool for practical conservation.

Particularly useful aspects of evaluating species vulnerability traits include:

1. In cases of foreknowledge of the onset of or reaching threshold levels of a particular threat (e.g. climate change, pollution, habitat loss, ocean warming), an assessment can be made of resulting species-specific effects and extinction risk in advance of the impacts.
2. Species experts are usually able to provide basic life history information about their taxa of interest, even when the more detailed and resource intensive information needed for applying the *IUCN Red List Categories and Criteria* is not available. The 'vulnerability traits' tool will allow some measure of a species' likely risk of extinction even when shortage of data necessitates a Data Deficient Red List assessment
3. Application of this trait based vulnerability assessment approach is likely to identify taxonomic or geographical species groups that remain unthreatened, while possessing traits associated with high vulnerability. Such species are likely to become the most quickly threatened, given increases in particular threats. This provides valuable information for conservation planning and prioritization.

The organizers wish to thank all participants for their generous contributions of time, energy, thought, goodwill and humour.

We are very grateful to **Imperial College London** for providing the venue and covering the workshop costs.

We'd like to thank **Georgina Mace**, **Jean-Christophe Vié** and **Simon Stuart** for their inputs and guidance both before and during the workshop. We hugely appreciate the help of **Sarah Snellin** and **Claire Santer** who provided excellent and patient administrative support.

Appendix 1: Workshop Participants

Participant	Affiliation	Email address
Ana Rodrigues	University of Cambridge	aslr2@cam.ac.uk
Andy Sheppard	CSIRO	Andy.Sheppard@csiro.au
Ben Collen	Zoological Society of London	ben.collen@ioz.ac.uk
Craig Hilton-Taylor	IUCN	Craig.Hilton-Taylor@ssc-uk.org
David Keith	New South Wales Department of Environment & Climate Change	david.keith@environment.nsw.gov.au
Georgina Mace	Imperial College London	g.mace@imperial.ac.uk
JB Mihoub	Muséum National d'Histoire Naturelle, Paris	mihoub@mnhn.fr
Jean-Christophe Vié	IUCN	jean-christophe.vie@iucn.org
Joaquin Hortal	Imperial College London	j.hortal@imperial.ac.uk
John Reynolds	Simon Fraser University	reynolds@sfu.ca
Jon Bielby	Imperial College London	jon.bielby@imperial.ac.uk
Kate Jones	Zoological Society of London	kate.jones@ioz.ac.uk
Keith Crandall	Brigham Young University	keith_crandall@byu.edu
Mar Cabeza	SEBI Climate Change Group	cabeza@cc.helsinki.fi
Neil Brummitt	RBG Kew	n.brummitt@rbgkew.org.uk
Nick Dulvy	Simon Fraser University	N.Dulvy@uea.ac.uk; nick.dulvy@cefas.co.uk
Paul Pearce-Kelly	Zoological Society of London	Paul.Pearce-Kelly@zsl.org
Resit Akçakaya	Stony Brook University	resit.akcakaya@gmail.com
Rich Grenyer	Imperial College London	grenyer@imperial.ac.uk
Rob Alkamade	Wageningen University	jrm.alkemade@mnp.nl
Rob Ewers	Imperial College London	robert.ewers@ioz.ac.uk
Rob Marchant	York University	rm524@york.ac.uk
Sarah Holbrook	Zoological Society of London	Sarah.Holbrook@ioz.ac.uk
Shyama Pagad	University of Auckland	s.pagad@auckland.ac.nz
Simon Butler	The University of Reading	s.j.butler@reading.ac.uk
Simon Stuart	IUCN	simon.stuart@iucn.org
Stephen Williams	James Cook University	stephen.williams@jcu.edu.au
Stu Butchart	BirdLife	Stuart.Butchart@birdlife.org.uk
Tom Meagher	University of St Andrews	trm3@st-and.ac.uk
Wendy Foden	IUCN	wendyfoden@gmail.com
Zoe Macavoy	Imperial College London	zoe.macavoy06@imperial.ac.uk

Appendix 2

Daily activities of the Species Vulnerability workshop

Day 1

- Welcome and introductions (Georgina Mace and Jean-Christophe Vié)
- Presentation: an introduction to the use of traits to determine vulnerability to extinction (Ben Collen)
- Presentation: an introduction to the impacts of climate change on species (Wendy Foden)
- Group discussion: participants discussed the definition of a 'trait' and establishing how these will be used
- Small group discussion and report back: traits associated with vulnerability to different **threat** types, namely habitat transformation, climate change, overexploitation, invasives and pathogens and pollution, were identified

Day 2

- Small group discussion and report back: the traits associated with different **taxonomic** groups were identified
- Group discussion: participants reached consensus on the **overall list** of traits associated with vulnerability to extinction

Day 3

- Small group discussion and report back: experts for each taxonomic group discussed the applicability of each of the previously identified traits for their taxonomic groups and attempted to apply the traits to real species examples from their groups

Day 4 (climate change modeling focus)

- Presentation: Using spatial modeling of habitat and demographic processes to determine species responses to climate change (Resit Akçakaya and David Keith)
- Group discussion:
    a. Methods for using the traits information to assess species, and integrating this into the IUCN Red Listing procedures
    b. Identification of the minimum list of key traits for assessing species' climate change driven vulnerability
    c. The role of bioclimatic modeling in assessing species climate change driven extinction risk