Optimizing Allocation of Management Resources for Wildlife

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Abstract: Allocating money for species conservation on the basis of threatened species listings is not the most cost-effective way of promoting recovery or minimizing extinction rates. Using ecological and social factors in addition to threat categories, we designed a decision-support process to assist policy makers in their allocation of resources for the management of native wildlife and to clarify the considerations leading to a priority listing. Each species is scored on three criteria at the scale of the relevant jurisdiction: (1) threat category, (2) consequences of extinction, and (3) potential for successful recovery. This approach provides opportunity for independent input by policy makers and other stakeholders (who weight the relative importance of the criteria) and scientists (who score the species against the criteria). Thus the process explicitly separates societal values from the technical aspects of the decision-making process while acknowledging the legitimacy of both inputs. We applied our technique to two Australian case studies at different spatial scales: the frogs of Queensland (1,728,000 km²; 116 species) and the mammals of the Wet Tropics bioregion (18,500 km²; 96 species). We identified 7 frog and 10 mammal species as priorities for conservation. The frogs included 1 of the 9 species classified as endangered under Queensland legislation, 3 of the 10 species classified as vulnerable, 2 of the 22 species classified as rare, and 1 of the 75 species classified as least concern. The mammals identified included 3 of the 6 species classified as endangered, 1 of the 4 species classified as vulnerable, 5 of the 11 species classified as rare, and 1 of the 75 species classified as least concern. The methods we used to identify species were robust to comparisons across the two taxonomic groups. We concluded that (1) our process facilitates comparisons of data required to make transparent, cost-effective, and strategic management decisions across taxonomic groups and (2) the process should be used to short-list species for further discussion rather than for allocating resources per se.

Keywords: anurans, conservation priorities, decision support, mammals, management effectiveness, management resources, species conservation

Optimización de la Asignación de Recursos para la Gestión de Vida Silvestre

Resumen: La asignación de dinero para la conservación de especies sobre la base de las listas de especies amenazadas no es la forma más rentable de promover la recuperación o de minimizar las tasas de extinción. Utilizando factores ecológicos y sociales adicionalmente a las categorías de amenaza, diseñamos un proceso de soporte de decisiones para asistir a los políticos en la asignación de recursos para la gestión de vida

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Introduction

The threat category of a species has been used in legislation to provide a statutory basis for government intervention to reduce the impact of threatening processes. Possingham et al. (2002) point out that it is inappropriate to rely solely on threatened species lists for resource allocation. Resources for conservation are invariably limited and allocating money on the basis of threat category alone is not the most efficient way of promoting recovery or minimizing extinction rates. Some highly threatened species can be secured only with expensive recovery efforts with little chance of success, whereas other less-threatened taxa can be secured by relatively modest interventions.

Preventing extinction is not the only conservation goal of governments. Values that the community attaches to particular species also influence government decision making. Thus even though most endangered species legislation aims to promote the recovery of species that have a high probability of extinction in the wild within a defined time frame, governments consider public preferences in deciding management priorities. For example, the U.S. General Accounting Office found that the U.S. Fish and Wildlife Service generally ignored most species highest on the priority (threatened) list, concentrating instead on those with “high public appeal” or “facing imminent recovery” (Raloff 1989). In 1986 the U.S. Fish and Wildlife Service directed 25% of all recovery funds not congressionally earmarked for specific species to just four animals—the American Peregrine Falcon (Falco peregrinus), southern sea otter (Enhydra lutris nereis), gray wolf (Canis lupus), and Aleutian Canada Goose (Branta canadensis). The U.S. General Accounting Office noted that none of these species was listed as endangered or even highly threatened throughout much of its range (Raloff 1989). In most jurisdictions policy makers use high-profile taxa as flagships for other conservation efforts. Thus, threat category or other criteria based solely on the opinions of ecological experts are not, and should not be, the only determinants of priorities for species management (Eaton et al. 2005).

Because resources for wildlife management are inevitably assigned on the basis of factors in addition to threat category, a transparent assignment process is highly desirable. Several such methods have been developed for various jurisdictions (e.g., Sparrowe & Wright 1975; Ahern et al. 1985; Millsap et al. 1990; Hall 1993; Avery et al. 1994; Molloy & Davis 1994; Warren et al. 1997), and the process outlined here has some elements in common with these methods. In addition, our approach provides opportunity for independent contributions from policy makers and/or stakeholders as well as scientists. We used two Australian case studies at different spatial scales to test the technique: the 116 species of frogs occurring in the state of Queensland (17,280,000 km²) and the 96 mammals of the Wet Tropics bioregion in northern Queensland (18,500 km²).

Methods

Criteria for Assignment of Species Priority

We used a risk-assessment framework as the starting point for assigning management priority. The concept of risk...
Assigning Management Priority to Wildlife

Before beginning the process, the makeup of the groups of policy makers and/or stakeholders and technical experts and the role of community stakeholders must be considered carefully. Technical experts should not be restricted to biologists and should include experts in community values (including indigenous values) to ensure that the scoring of the social components of both the CoE and PISR criteria is based on similar levels of data, rigor, and expert opinion. The number of people scoring influences the variance and therefore the robustness of the scores.

The final groupings of policy makers, stakeholders, and technical experts meet to discuss the definitions of the various components of the CoE and PISR criteria to resolve ambiguities and ensure a common approach. The policy makers also need to resolve definitional matters such as the jurisdiction, the categories and criteria for threatened species (this is particularly important when these differ in different jurisdictions, as they do in Australia), and the taxonomic groups to be considered.

A focus group of policy makers and stakeholders weights the components of the CoE criterion (Table 1) and the PISR criteria (Table 2). For each criterion the group allocates 100 points among the components with a Delphi technique (Veal 1992) to establish their perceptions of the relative importance of the components. The group can assign a weighting of zero to one or more components of each criterion but not to that criterion as a whole. Weighting is constant across major taxonomic groups.

The group(s) of technical experts then scores each species against each of the component criteria. The technical experts are not made aware of the policy makers or stakeholders' weightings until their scoring is completed. Technical experts record their level of confidence in each component score on an agreed-upon scale (we used four points). Although these rankings are not incorporated in the final species rankings, they help overcome the reluctance of technical experts to score in the face of uncertainty and provide important additional information for policy makers. This approach is particularly useful for scoring social values, where specific research examining the social values of a taxon is usually lacking, but various indicators (e.g., use of species as logos, in tourism literature, or in indigenous art) may be available for some species.

When the scoring is complete, each species is assigned to a category of threat as defined by the relevant legislation, and its score for CoE is plotted against its score for PISR (Fig. 1). The technical experts then discuss the scores for the individual components of CoE and PISR for each species to identify instances where low scores for particular anthropogenic components prevent threatened species from otherwise having a high rank. For example, endangered species with low scores for social values may highlight a need for public education initiatives or research to determine what the social values are if the confidence score is also low. This issue is especially important for noncharismatic taxa. In addition, species...
that rank highly on all aspects of PfSR except community support are considered likely targets for community engagement with the key stakeholder groups that either oppose or are indifferent to recovery actions.

The technical experts then draw up a short list of species and their scores for consideration by the policy makers. This list should include all species listed as critically endangered or endangered and the species

Table 1. Components of the criterion consequences of extinction of the species within the jurisdiction.

<table>
<thead>
<tr>
<th>Value</th>
<th>Score = 4</th>
<th>Score = 3</th>
<th>Score = 2</th>
<th>Score = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecological role: the role of the species in ecological interactions</td>
<td>keystone species or structuring species, top predator, significant dispersal or pollination agent</td>
<td>species of significance in ecosystem processes but shares this role with one or two other species in the same major taxonomic group (e.g., mammals) in the ecosystem(s) in which it lives</td>
<td>role in ecosystem processes shared by three, four, or five other species in the same major taxonomic group (e.g., mammals) in the ecosystems in which it lives</td>
<td>role in ecosystem processes shared by more than five other species in the same major taxonomic group (e.g., mammals) in the ecosystems in which it lives</td>
</tr>
<tr>
<td>Evolutionary values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genetic uniqueness of species in jurisdiction</td>
<td>species does not occur outside jurisdiction</td>
<td>species comprises a evolutionarily significant unit (Moritz 1994)</td>
<td>species shows evidence of genetic structuring or proven geographic disjunction, which suggests low gene flow between or within jurisdiction; rest of range or population structure unknown</td>
<td>species in jurisdiction not distinct genetically from range outside jurisdiction</td>
</tr>
<tr>
<td>Taxonomic singularity in a global context</td>
<td>species in monotypic family</td>
<td>species in monotypic genus</td>
<td>species in genus with two, three, or four species</td>
<td>species in genus with more than four species</td>
</tr>
<tr>
<td>Conservation responsibility of jurisdiction for species</td>
<td>species limited to jurisdiction or threatened everywhere outside jurisdiction</td>
<td>&gt;30% of known global population in jurisdiction; species secure in range outside jurisdiction</td>
<td>15-30% of known global population in jurisdiction; species secure in range outside jurisdiction</td>
<td>&lt;15% of known global population in jurisdiction; species secure in range outside jurisdiction</td>
</tr>
<tr>
<td>Social values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social values including both nonuse values and use values</td>
<td>species (as distinct from its habitat) of high social value to mainstream community in relevant jurisdiction; subject of an international convention to which relevant government is signatory; flagship species</td>
<td>species (as distinct from its habitat) of high social value to at least one major stakeholder group (other than western scientists) within jurisdiction (e.g., mainstream conservation group)</td>
<td>species (as distinct from its habitat) of high social value to at least one special interest group in the jurisdiction (e.g., local specialist conservation group such as a bat group)</td>
<td>generally unknown to wider community or actively disliked (e.g., pest)</td>
</tr>
</tbody>
</table>

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*aThe final score for each species is the sum of the weighted components.
bSpecies in different taxonomic groups are unlikely to have exactly the same ecological role.
cThe degree of monotypy at the level of family and genus at a global scale. This criterion reflects the premise that the conservation of a species in a monotypic family should have precedence over a species from a monotypic genus and that both should have priority over species from polytypic genera.
dNonuse values include bequest value (value current generation places on ensuring the species exists for their children), existence value (benefit created by knowing species exists), option value (value of conserving a species so that a number of other values may be realized in the future), quasi-option value (values people place on gaining further knowledge before making a decision that may result in the extinction of the species), vicarious value (welfare obtained via indirect consumption of the species by knowing that other people use it, through, e.g., books and documentaries).
eUse values may be direct or indirect and include buying, selling, processing, moving, or gaining any benefit from the wildlife including financial values derived from use, value of forage species for economically important or charismatic species, historic cultural values, indigenous-use values, information values (scientific, educational, medical, spiritual, and religious, artistic), recreational values, visual amenity values. Cultural values can be use or nonuse values.
Table 2. Components of the criterion potential for successful recovery of the species within the jurisdiction.\textsuperscript{a}

<table>
<thead>
<tr>
<th>Component</th>
<th>Score = 4</th>
<th>Score = 3</th>
<th>Score = 2</th>
<th>Score = 1</th>
</tr>
</thead>
</table>
| Threatening processes
| knowledge of processes threatening species in jurisdiction\textsuperscript{b} | relative importance well understood | identified but relative importance poorly understood | species known or believed to be declining; threatening processes unknown | species not known to be in decline |
| capacity to effect recovery by controlling threatening processes through actions taken within jurisdiction\textsuperscript{c} | very high likelihood for improved control | reasonable likelihood of improved control | some capacity for improved control | no additional capacity to improve control |
| Ongoing management
| financial and other costs of ongoing management (as distinct from monitoring) to ensure recovery\textsuperscript{d} | no need for ongoing management if significant threatening processes are stopped | ongoing management can be accommodated within normal budget of relevant agencies if significant threatening processes are stopped | controlling the threatening processes will require a major long-term commitment of dedicated funding | not possible (or necessary) to control the threatening processes within the jurisdiction or there are no known threatening processes |
| community support for on-the-ground recovery and implementation of actions\textsuperscript{e} | sufficient to ensure implementation of actions for the recovery of species with regular agency review | sufficient to assist recovery activities with agency management | neutral or polarized about measures required to ensure recovery or to list species as secure; recovery program needed | likely that community will successfully resist measures required to effect recovery; considerable ongoing recovery actions, including enforcement, required |
| Biological potential for recovery
| biological potential for recovery of species in a management timeframe in the absence of anthropogenic threats\textsuperscript{f} | species has capacity to double its population size in less than 1 year | species has capacity to double its population size in less than 5 years | species has capacity to double population size in less than 10 years or generative capacity unknown | species must take more than 10 years to double population size |

\textsuperscript{a}The final score for each species is the sum of the weighted components.
\textsuperscript{b}The success of management intervention depends on an understanding of the threatening processes. If the threatening processes are not understood, management intervention will not be evidence based and is unlikely to be successful.
\textsuperscript{c}Some threatening processes (e.g., global warming) are impossible to control via unilateral management intervention from within a jurisdiction. The unilateral expenditure of scarce management dollars on a single species within a jurisdiction is unlikely to be cost-effective under these circumstances.
\textsuperscript{d}Allocating resources to species for which the threatening process(es) can be countered by a single action rather than requiring expensive long-term management intervention is usually cost-effective.
\textsuperscript{e}Giving priority to species for which there is community commitment to conduct or contribute to recovery is usually cost-effective. The likely level of voluntary compliance with regulations to control threatening processes is also important.
\textsuperscript{f}If this information is not available, use a surrogate based on age at maturity, fecundity per year, and survivorship. Species with a high rate of natural increase are more likely to respond to management intervention in a time frame relevant to managers, which is likely to depend on economic and political cycles.

identified as priorities on the basis of their weighted and unweighted scores for CoE and PfSR.

The scores and comments on important issues that arise during the scoring process are stored in a database to facilitate future evaluations and comparisons. Regular rescoring incorporating increased knowledge influences the ranking of species and therefore allocation of resources.

Case-Study Methods

Establishing the Weightings and Scoring

Experienced senior policy makers from the Queensland Environment Protection Agency participating in a workshop were briefed on the process by the senior author. The group then weighted the components of the CoE and PfSR criteria, distributing a total of 100 points by
Figure 1. The consequences of extinction and potential for successful recovery scores for the two case studies for taxa at various categories of threat under the Queensland Nature Conservation Act 1992 and subordinate legislation: (a) scores of the technical experts for frogs; (b) scores of the technical experts for frogs multiplied by the policy makers’ weightings; (c) scores of the technical experts for the mammals of the Wet Tropics Bioregion; (d) scores of the technical experts for mammals multiplied by the policy makers’ weightings; (e) unweighted scores for both the frogs and the mammals; and (f) weighted scores for both the frogs and the mammals. Some data points represent more than one species. The species identified as high priority are circled (high-priority species codes: frogs: Lbre, Litoria brevipalmata; Lcoo, Litoria cooloolensis; Lfre, Litoria freycineti; Lolo, Litoria olongburensis; Nben, Notaden bennetti; Pcov, Pseudophryne covacevichae; Tple, Taudactylus pleione; mammals: Btro, Bettongia tropica; Dmag, Dasyurus maculatus gracilis; Dbe, Dendrolagus bennettianus; Dlum, Dendrolagus lumholtzi; Hlem, Hemibelideus lemuroides; Oana, Ornithorhynchus anatinus; PauU, Petaurus australis unnamed subsp; PeGra, Petaurus gracilis; Parc, Pseudochirops archeri; Pber, Pseudochirulus herbertensis.) The units of scoring are detailed in Tables 1 and 2.
components of the CoE criterion (potential range 4–16) and the PfSR criteria (potential range 6–24).

Selecting High-Priority Species for Resource Allocation

To identify species of highest priority for resource allocation, we plotted the total CoE scores against the total PfSR scores, coding each species on the basis of its status under the Queensland Nature Conservation Act 1992. High-priority species were toward the top right-hand corner of the graph. Assessing species graphically reduced the risk of including species that rank very highly on one axis but only low or moderately on the other. We identified high-priority species on the basis of natural breaks in the graphs. In addition, we reviewed the reasons why species that were classified as endangered occurred outside this region on the graphs and whether their scores were justified.

Results

Frogs of Queensland

The technical experts scored 116 native frog species recorded from Queensland, excluding the species that were assessed as presumed extinct. Nine were classified as endangered, 10 as vulnerable, 22 rare, and 75 least concern under the Queensland Nature Conservation Act 1994 and subordinate legislation. The seven frogs identified as priority species by the weighted scores for the CoE and PfSR criteria (Fig. 1b; Table 3) included one species classified as endangered under the Queensland legislation, three species classified as vulnerable, two species classified as rare, and one species classified as least concern. These species occupied a range of habitats. Five species occur in southeastern Queensland, an area with extensive coastal development. Four of these frogs were also identified as priority by the unweighted scores (Fig. 1a).

The experts had high confidence in their scores (33–38 out of a possible 40) for all seven animals identified as high priority. The overall median for the confidence scores for all frogs was 36, and there were no species with confidence scores <30. The Spearman rank correlations between the relevant confidence scores and the weighted CoE scores was significant (CoE weighted vs. CoE confidence \(n = 116, r = 0.246, p = 0.008\)) but the corresponding relationship for the unweighted scores was not significant (CoE unweighted vs. CoE confidence \(n = 116, r = 0.153, p = 0.647\)). In addition, there were significant negative Spearman correlations between the weighted and unweighted PfSR scores and the associated confidence scores (PfSR weighted vs. PfSR confidence \(n = 116, r = -0.512, p = 0.000\); PfSR unweighted vs. PfSR confidence \(n = 116, r = -0.522, p = 0.000\)).

Of the nine frogs classified as endangered in Queensland, only Taudactylus pleione scored high on both the CoE and the PfSR criteria (Table 4). Taudactylus rheophilus and Taudactylus eungellensis scored high on CoE but had a moderate score for PfSR. The remaining endangered frog species received moderate scores for both criteria. These observations were true for both weighted and unweighted scores, although endangered species tended to have higher and more similar CoE scores when weighting was used. Notaden bennetti, which is classified as least concern, made it into the high-priority group predominantly because of relatively high scores for the following components: community commitment to appropriate recovery action, biological potential for recovery, knowledge of processes threatening species in the jurisdiction and their relative importance, capacity to effect recovery by actions taken within the jurisdiction, and conservation responsibility of the jurisdiction for the species.

Mammals of the Wet Tropics Bioregion

The technical experts scored 96 species of mammals, of which 6 were classified as endangered, 4 vulnerable, 11 rare, and 75 least concern under the Queensland nature conservation legislation. The species ranking highest on
Table 4. Scores for Queensland (Qld) frog species and mammal species of the Wet Tropics bioregion listed as endangered and/or selected as high-priority species for management intervention on the basis of the weighted scoring criteria for consequences of extinction and potential for successful recovery.

<table>
<thead>
<tr>
<th>Familya</th>
<th>Scientific name</th>
<th>Common nameb</th>
<th>Status under Qld legislation</th>
<th>CoE score (unweighted)</th>
<th>CoE score (weighted)</th>
<th>PfSR score (unweighted)</th>
<th>PfSR score (weighted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frogs of Queensland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Litoria nannotis</em></td>
<td>waterfall frog</td>
<td>endangered</td>
<td>14</td>
<td>266</td>
<td>12</td>
<td>250</td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Litoria pearsoniana</em></td>
<td>cascade treefrog</td>
<td>endangered</td>
<td>12</td>
<td>266</td>
<td>11</td>
<td>240</td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Litoria rheocola</em></td>
<td>common mist frog</td>
<td>endangered</td>
<td>14</td>
<td>266</td>
<td>12</td>
<td>250</td>
</tr>
<tr>
<td>Myobatrachidae</td>
<td><em>Mixophyes fleayi</em></td>
<td>Fleay’s barred frog</td>
<td>endangered</td>
<td>12</td>
<td>244</td>
<td>12</td>
<td>250</td>
</tr>
<tr>
<td>Myobatrachidae</td>
<td><em>Mixophyes iteratus</em></td>
<td>giant barred frog</td>
<td>endangered</td>
<td>10</td>
<td>222</td>
<td>13</td>
<td>260</td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Nyctimystes dayi</em></td>
<td>Australian lacelid</td>
<td>endangered</td>
<td>14</td>
<td>266</td>
<td>12</td>
<td>250</td>
</tr>
<tr>
<td>Myobatrachidae</td>
<td><em>Taudactylus euangellensis</em></td>
<td>Eungella dayfrog</td>
<td>endangered</td>
<td>16</td>
<td>311</td>
<td>12</td>
<td>250</td>
</tr>
<tr>
<td>Myobatrachidae</td>
<td><em>Taudactylus pleionae</em></td>
<td>Kroombit tinkerfrogd</td>
<td>endangered</td>
<td>16</td>
<td>311</td>
<td>15</td>
<td>290</td>
</tr>
<tr>
<td>Myobatrachidae</td>
<td><em>Taudactylus rheophilus</em></td>
<td>northern tinkerfrog</td>
<td>endangered</td>
<td>16</td>
<td>311</td>
<td>12</td>
<td>250</td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Litoria freycineti</em></td>
<td>Wallum rocketfrogd</td>
<td>vulnerable</td>
<td>10</td>
<td>200</td>
<td>14</td>
<td>280</td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Litoria olongburensis</em></td>
<td>Wallum sedgefrogd</td>
<td>vulnerable</td>
<td>12</td>
<td>244</td>
<td>14</td>
<td>280</td>
</tr>
<tr>
<td>Myobatrachidae</td>
<td><em>Pseudophryne covacevichae</em></td>
<td>magnificent broodfrogd</td>
<td>vulnerable</td>
<td>13</td>
<td>232</td>
<td>15</td>
<td>300</td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Litoria brevipalmata</em></td>
<td>green thighed frogd</td>
<td>rare</td>
<td>12</td>
<td>244</td>
<td>13</td>
<td>270</td>
</tr>
<tr>
<td>Hylidae</td>
<td><em>Litoria cooloolensis</em></td>
<td>Cooloola sedgefrogd</td>
<td>rare</td>
<td>14</td>
<td>266</td>
<td>15</td>
<td>300</td>
</tr>
<tr>
<td>Myobatrachidae</td>
<td><em>Notaden bennetti</em></td>
<td>holy cross frogd</td>
<td>least concern</td>
<td>9</td>
<td>188</td>
<td>15</td>
<td>290</td>
</tr>
<tr>
<td>Mammals of the Wet Tropics bioregion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dasyuridae</td>
<td><em>Dasyurus maculatus gracilis</em></td>
<td>spotted-tailed quoll (northern subspecies)d</td>
<td>endangered</td>
<td>14</td>
<td>289</td>
<td>14</td>
<td>260</td>
</tr>
<tr>
<td>Dasyuridae</td>
<td><em>Dasyurus maculatus macleayensis</em></td>
<td>bare-rumped sheathail bat</td>
<td>endangered</td>
<td>8</td>
<td>178</td>
<td>11</td>
<td>220</td>
</tr>
<tr>
<td>Emballonuridae</td>
<td><em>Saccolaimus saccolaimus nudiculatus</em></td>
<td>Semon’s leaf-nosed bat</td>
<td>endangered</td>
<td>6</td>
<td>133</td>
<td>10</td>
<td>210</td>
</tr>
<tr>
<td>Hipposideridae</td>
<td><em>Hipposideros semoni</em></td>
<td>Semon’s leaf-nosed bat</td>
<td>endangered</td>
<td>16</td>
<td>333</td>
<td>13</td>
<td>230</td>
</tr>
<tr>
<td>Petauridae</td>
<td><em>Petaurus gracilis</em></td>
<td>mahogany gliderd</td>
<td>endangered</td>
<td>16</td>
<td>311</td>
<td>15</td>
<td>320</td>
</tr>
<tr>
<td>Potoroidae</td>
<td><em>Petaurus australis</em></td>
<td>yellow-bellied gliderd</td>
<td>vulnerable</td>
<td>13</td>
<td>278</td>
<td>15</td>
<td>280</td>
</tr>
<tr>
<td>Petauridae</td>
<td><em>Petaurus australis</em></td>
<td>(northern subspecies)</td>
<td>endangered</td>
<td>15</td>
<td>299</td>
<td>13</td>
<td>250</td>
</tr>
<tr>
<td>Macropodidae</td>
<td><em>Dendrolagus bennettianus</em></td>
<td>Bennett’s tree-kangarood</td>
<td>rare</td>
<td>15</td>
<td>299</td>
<td>13</td>
<td>250</td>
</tr>
<tr>
<td>Macropodidae</td>
<td><em>Dendrolagus lumholtzi</em></td>
<td>Lumholtz’s tree-kangaroo</td>
<td>rare</td>
<td>15</td>
<td>299</td>
<td>13</td>
<td>250</td>
</tr>
<tr>
<td>Pseudocheiridae</td>
<td><em>Hemibelideus lemuroides</em></td>
<td>lemuroid ringtail possumd</td>
<td>rare</td>
<td>17</td>
<td>321</td>
<td>13</td>
<td>250</td>
</tr>
<tr>
<td>Pseudocheiridae</td>
<td><em>Pseudochirops archeri</em></td>
<td>green ringtail possumd</td>
<td>rare</td>
<td>14</td>
<td>266</td>
<td>13</td>
<td>250</td>
</tr>
<tr>
<td>Pseudocheiridae</td>
<td><em>Pseudochirulus berberiensis</em></td>
<td>Herbert River ringtail possumd</td>
<td>rare</td>
<td>14</td>
<td>266</td>
<td>13</td>
<td>250</td>
</tr>
<tr>
<td>Pseudocheiridae</td>
<td><em>Pseudocheirus platypus</em></td>
<td>platypusd</td>
<td>least concern</td>
<td>13</td>
<td>300</td>
<td>14</td>
<td>280</td>
</tr>
</tbody>
</table>

a The species are sorted according to status under Queensland Nature Conservation Act 1992 and subordinate legislation and then taxonomically by scientific name.
b Common names are taken from WildNet, the Queensland Environmental Protection Agency’s wildlife database.
c Key: CoE, consequences of extinction; PfSR, potential for successful recovery.
d Species identified as high priority through scoring process.
the scoring criteria were examined in more detail (Figs. 1c & 1d). The technical experts identified 9 species as worthy of special consideration (Table 4), all of which had final confidence ranking at or above the overall median of 29 (out of a possible 40), indicating that the technical experts were relatively confident in their scoring. These same 9 species plus the platypus (Ornithorhynchus anatinus) were identified after the policy makers’ weightings had been used to adjust the scores of the technical experts. Although O. anatinus is listed as least concern under the legislation, the experts scored it high for social value and community commitment to appropriate recovery action, two components that policy makers also gave high weightings.

The nine species identified by both groups included three species classified as endangered under the Queensland legislation (Bettongia tropica, Dasyurus maculatus gracilis, and Petaurus gracilis); one species classified as vulnerable (Petaurus australis unnammed subs); and five species classified as rare (Dendrolagus bennettianus, Dendrolagus lumholtzi, Hemibelideus lemuroides, Pseudochirops archeri, Pseudochirulus berbentinus).

Three bat species listed as threatened had relatively low confidence scores (Hipposideros semoni and Saccolemus saccolaimus nudicluniatus are endangered; Murina florium is vulnerable). We recommend that all these species be considered priorities for research.

The Spearman rank correlation between the relevant confidence scores and the weighted CoE scores and PFISR scores were weakly positive and significant (CoE weighted vs. CoE confidence n = 96, r = 0.226, p = 0.027; PFISR weighted vs. PFISR confidence n = 96, r = 0.284, p = 0.005). The corresponding relationships between the confidence scores and the unweighted CoE scores and PFISR scores were not significant (CoE unweighted vs. CoE confidence n = 96, r = 0.139, p = 0.17; PFISR unweighted vs. PFISR confidence n = 96, r = 0.100, p = 0.33).

Discussion

In their documentation of the IUCN Red List Categories and Criteria, the IUCN points out (IUCN 2001) that the category of threat is not necessarily sufficient to determine priorities for conservation action. Rather, a system for assessing priorities for action will include numerous other factors concerning conservation action such as costs, logistics, chances of success, and other biological characteristics. A further argument for not relying solely on extinction risk is the rapid increase in the number of species listed as globally threatened, which has increased dramatically between the 1996/1998 and 2006 IUCN Red Lists (69%, 91%, and 37% increase in listings as critically endangered, endangered, and vulnerable, respectively [IUCN 2006]). Focusing on threat category as the sole criterion for allocating resources may overemphasize the plight of the taxa under greatest threat and prevent the implementation of effective (and cost-effective) actions for less seriously threatened taxa (Possingham et al. 2002).

Our process is designed to present the additional data required to make cost-effective and strategic management decisions in a way that can inform such decisions and make them more transparent. It is not intended to replace human judgment; indeed, judgment is required at every step in the process. Neither does it provide an unambiguous ranked list of priorities; rather, it identifies clusters of species that score highly on the basis of a range of components that can be identified and considered. The process should be used to short-list species for further discussion rather than for allocating resources per se.

Uses of the Process

Short-Term Uses

The process outlined here is a dynamic decision support technique that will change with additional and better knowledge from research and other information (e.g., habitat loss, changing social values). Thus, the scoring needs regular reassessment to incorporate additional information. The method was designed to apply directly, as in the above case studies, to short-listed species for management action, research, or extension (community outreach) efforts.

The method is also useful to assure that no important species is overlooked in the process of resource allocation (e.g., because it is small or dull). Species are often designated as rare when they are really data deficient (the term used by IUCN 2001), and rare or data deficient species that score highly with respect to the CoE and PFISR criteria are obvious priorities for research. Threatened species that scored high on all aspects of PFISR, except community...
commitment to appropriate recovery action, merit special consideration to determine whether they should be a priority for community engagement. Although community outreach is likely to be appropriate for species with a low public profile, it may not be appropriate when public opinion is polarized. *P. gracilis* scored high on most aspects of PfSR. Nevertheless, the score for community commitment to appropriate recovery was low. This species occurs in a narrow strip of coastal woodlands about 110–130 km long and is threatened because of an extreme loss of habitat by tree clearing mainly for agriculture (see Tisdell et al. 2005). The funds expended on public education have been significant, but the target group with the most significant influence on the conservation of the species, a small group of landowners, has not been influenced and further outreach is unlikely to be cost-effective.

Alternatively, the methodology could be used in reverse to systematically unpack and demystify a proposal to spend large amounts of public money on the management of a species of high social value but of low extinction risk. This deconstruction may not change the outcome of the decision but will make the basis for the decision much more transparent to all stakeholders. We consider that decisions that reflect social values are too often disguised as scientific decisions. That approach diminishes the legitimacy of both science and social values and may lead to overspending on science in an attempt to use scientific criteria to justify decisions based largely on social values (e.g., some of the initiatives to conserve the Wet Tropics population of the Southern Cassowary [Casuarius casuarius johnsonii] [QPWS 2002] or the Southeast Queensland bioregion population of the koala [Phascolarctus cinereus] [EPA 2005]).

In addition, a process such as this one to short-list species for resource allocation should reduce the pressure on governments to (1) compromise the listing of species under endangered species legislation that should strictly accord with the agreed criteria for measuring or estimating the category of threat or (2) list species over small spatial scales that are not biologically relevant as a means of justifying decisions that reflect other stakeholder values, particularly social values (as has occurred in Queensland with the recent listing of the Southeast Queensland bioregion population of the koala, which is listed as vulnerable under the Queensland Nature Conservation Regulation 1994). Listing of species of low extinction probability as threatened should not be used as means of protecting threatened habitats or ecosystems (C. Moritz, unpublished). The latter should be protected through appropriate specific legislation. Nonetheless, if several species from the same habitat or ecosystem are ranked highly, our process also has the potential to inform priorities for ecosystem conservation. For example, if our process were applied to several major taxonomic groups and identified several species in addition to the frog *N. bennetti* (see below) as priorities as a result of clearing and agriculture in the brigalow belt, desert uplands, and eastern mulga bioregions, this information would strengthen the case for additional national parks in these bioregions.

**Long-Term Uses: Measuring the Effectiveness of Recovery Actions**

Our process could also be used to track temporal changes in a taxon’s profile that influences policy and operational decisions over time. A series of repeated profiles could be used to indicate whether resources invested in priority species have been effective and indicate when changes in investment are required. The scores of species assessed as having high PfSR should shift rapidly if recovery actions are effective. The advantages of having the capacity to track changes in species scores over time establishes the need to store such scores and the details of the rules for assigning scores and making subsequent decisions in a suitable database in a format that is understandable by nonspecialists.

**Examples of Use**

**Improving the Process**

Our experts differed in the initial scoring of frogs. Some of these differences were clearly the result of differing interpretation of the category descriptions (Tables 1 & 2). Other discrepancies resulted from the experts’ different levels of familiarity with various species or the distribution of regional ecosystems. These differences were quickly resolved through a group process in which unpublished information was shared.

One of the main values of a system of prioritization, such as this one, is the process of evaluating each taxon in a regular and formalized way (Ahern et al. 1985). Such evaluations can provide a foundation for the development and consideration of strategic options, which can, in turn, form the foundation of long-range action plans. With this goal in mind, we suggest that community stakeholders could play a valuable role in the process, despite the reluctance of many wildlife managers to support such a comanagement approach (Miller & Jones 2005). The cost of such an approach needs to be considered in the context of the costs of (1) reacting to the demands of special interests groups when they are unhappy with a decision made in what they perceive to be a nontransparent manner and (2) promoting parochial causes that are irrelevant for protection of threatened species.

**Using the Process for Short-Listing Species Rather than Prioritization**

The Wet Tropics bioregion is atypical for Australia because rainforest habitats predominate. Consequently, many species considered in our Wet Tropics case study...
have very restricted geographical distributions and are classified as rare. Nonetheless, they occur at high densities in reasonably secure habitats if one does not consider climate change.

Of the mammals identified with high scores for CoE (Figs. 1c & 1d), H. lemuroides, P. archeri, P. berbertensis, and Dendrolagus bennetti are restricted endemics and probably require little management apart from continuing to protect the rainforest. The situation may be very different in bioregions in which species have much wider but more fragmented distributions because of a natural mosaic in the vegetation cover and fragmentation induced by clearing for agriculture. Many species in such regions are classified as least concern (which suggests that the criteria defined by the Nature Conservation Act Qld 1992 and its subordinate legislation may have been used incorrectly) but may be under greater threat and require more management than the restricted endemics of the Wet Tropics. For example, clearing and agriculture in the brigalow belt, desert uplands, and eastern mulga bioregions in Queensland, especially along the valleys have had a huge impact on the habitat of the frog, N. bennetti, which is listed as least concern but was identified as a species worthy of prioritization for the allocation of resources by our process. Eaton et al. (2005) also noted that using the IUCN categories and criteria at regional levels for determining the category of threat tends to classify species that have declined substantially but remain common as being at low probability of extinction. A process such as the one described here provides a transparent means of deciding whether such species should be a focus of conservation efforts. In contrast the frog, Litoria cooloolensis, which we also identified as a priority species, mainly occurs in a protected area (Great Sandy National Park) and its potential for recovery is high with little or no further activity. These complexities highlight the need to use the process to short-list species for further consideration rather than to allocate funding based on the scores alone.

Technical Matters to Be Considered

Scoring Unknowns

For most criteria we scored unknowns as 1. This approach was appropriate for the social and management criteria (social values, threatening process, ongoing management). For example, if the social value of a species is unknown because it has a low public profile, it is appropriately scored as 1 (Tables 1 & 2). Nevertheless, having conducted the case studies, we consider that scoring unknowns as 1 may not be appropriate for the components of the criteria reliant on biological knowledge: ecological values, evolutionary values, and biological potential for recovery. There are several possible approaches to dealing with this uncertainty, including taking a conservative approach and scoring these components as 3 or 4, or using the methods developed to incorporate uncertainty in the IUCN criteria such as incorporating intervals rather than scalar values in scores (Akçakaya & Ferson 2001).

Scoring Category of Threat

At a regional scale, the category of threat assigned to a species is typically defined by regulations associated with threatened species or nature conservation legislation. Unfortunately, this listing may lag behind current knowledge. For example, some Queensland frogs, such as Rheobatrachus spp., Taudactylus diurnus, Litoria lorica, and Litoria nyakalensis, have not been seen for a considerable time despite efforts to locate populations (McDonald 2002), yet there is opposition to their being listed as presumed extinct in case they are rediscovered. Such species would also be assessed differently in the biological potential for recovery if presumed extinct rather than endangered. We used expert opinion on the extinction status of these species rather than their statutory listing as explained earlier. Spending scarce conservation funding on species that are probably extinct in the wild is likely to be a poor investment. Equally, breeding species that exist only in captivity and repatriating them to the wild should not be seen strictly as a recovery action but must be viewed in the context of associated activities and costs (Siegel & Dodd 2002).

Scoring Social Values

In the case studies all scorers were scientists and/or conservation managers, but some had problems differentiating between the use and nonuse components of social values. This problem was addressed by collapsing the categories of social value into one. Social values take considerable time and resources to measure, but we found them relatively unambiguous to score with the criteria outlined in Table 1.

Use of Process in Different Jurisdictions

The Wet Tropics Bioregion includes the Wet Tropics World Heritage Area, an area of high endemism. Consequently, the mammalian fauna is generally highly restricted and charismatic and occurs in an environment with a history of significant research effort and very high social value. This situation may have inflated the scores for the ecological and social components of the CoE criterion in this case study. Some species also scored high in the PESR criterion despite the looming impact of climate change (Williams et al. 2003). Factors such as these should be considered when comparing the unweighted scores from different jurisdictions.
Use of Process across Broad Taxonomic Groupings

Comparisons of assigned scores across major taxonomic groups may be less meaningful than comparisons within groups (Ahern et al. 1985). Thus, we used our process separately for different taxonomic groups in our case studies, acknowledging that in the end, priorities will have to be set across major taxonomic groupings. Nevertheless, comparison of the scores across the two taxa we used as case studies (Figs. 1e & 1f) suggested that the process is robust across taxonomic groups if there is careful training to ensure that experts are interpreting the criteria in a similar manner.

Conclusions

Our approach addresses the problem of using threatened species lists for resource allocation by providing a technique for collecting and presenting the additional data required to make cost-effective and strategic wildlife management decisions in a way that informs such decisions and makes them more transparent. Scientists, policy makers, and other stakeholders all have input into the decision-making process. The process provides the conceptual framework for the Back on Track program being developed by the EPA in Queensland and could easily be adapted to other jurisdictions or special interest groups. For example, in Australia, stakeholder groups have access to significant regional funding for natural resource management from the Natural Heritage Trust and the National Action Plan for Salinity and Water Quality (http://www.nrm.gov.au/index.html). At the regional level both these programs are driven by a single regional plan, developed by local communities and supported by government and the best available science to improve natural resources on a regional scale. A process such as the one outlined here has the potential to inform the development of such regional plans.

Acknowledgments

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