Applying Science to Pressing Conservation Needs for Penguins

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Running Head: Pressing Needs for Penguins

Keywords:
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Article Impact Statement: Safeguarding the future of penguins requires collaboration among scientists and policymakers and immediate, informed conservation action.
Abstract

More than half of the world's 18 penguin species are declining. We, the Steering Committee of the International Union for Conservation of Nature Species Survival Commission Penguin Specialist Group, voted on the penguin species in most critical need of conservation action. Because of their small or rapidly declining populations, the top three species identified in this process were the African penguin (*Spheniscus demersus*), Galápagos penguin (*Spheniscus mendiculus*), and Yellow-eyed penguin (*Megadyptes antipodes*). To persist, these species require immediate scientific collaboration and policy intervention. In addition to highlighting the three priority species, we used a pairwise ranking approach to prioritize research and conservation needs for all penguins. Among the 12 cross-taxa research areas we identified, we ranked quantifying population trends, estimating demographic rates, forecasting environmental patterns of change, and improving knowledge of fisheries interactions as the highest priorities. The highest ranked conservation needs were to enhance marine spatial planning, improve stakeholder engagement, and develop disaster management and species-specific action plans. As part of our discussions, we identified four avenues for improving translation of science into effective conservation for penguins. First, the scientific community and funding bodies must recognize the importance of and support long-term research. Second, research on and conservation of penguins must expand its focus to include the non-breeding season and the juvenile stage. Third, marine reserves must be designed at ecologically appropriate spatial and temporal scales. Lastly, communication between scientists and decision makers must be improved with the help of individual scientists, interdisciplinary species-specific working groups, and international working groups.
Introduction

Penguins, among the most iconic animals on the planet, are in trouble. Ten of the 18 recognized penguin species are considered threatened (IUCN 2018, Table 1), making them the most threatened group of seabirds after albatrosses and petrels (Croxall 2012). More than half of the 18 species are in decline and species with stable or increasing global populations are sometimes regionally in decline (e.g. Magellanic penguins Spheniscus magellanicus: Pozzi et al. 2015). For some species, data are insufficient to estimate global population size (e.g. see below on Galápagos Penguins Spheniscus mendiculus).

The International Union for Conservation of Nature Species Survival Commission (IUCN SSC) Specialist Groups consist of members that represent the highest level of scientific rigor and expertise regarding the conservation of the species within their purview (IUCN 2017). The IUCN SSC Penguin Specialist Group (PSG) Steering Committee (Supporting Information 1) held a 2-day conservation strategy workshop to: 1) develop a consensus on the penguin species of most immediate conservation concern and 2) prioritize gaps in penguin research and conservation. Workshop attendees represented eight countries and a broad expertise on penguins (Supporting Information 1), having also consulted with and/or drawn from the expertise and published work regarding the species they represented. The goal of these intensive discussions and structured ranking processes was to foster conservation action on behalf of penguins as a taxon, recognizing that a lack of consensus among scientists on priorities and approaches can impede conservation (e.g. in the case of African penguin Spheniscus demersus: Holcombe 2015).
Priorities for Penguins

In a facilitated session, we collated our collective experience and knowledge, together with knowledge gleaned from the many penguin scientists and publications, to identify conservation and research needs. We then grouped these needs into broader themes (e.g. research on microplastics and harmful algal blooms were included under "marine pollution") (Supporting Information 2), leading to nine conservation priorities and twelve research priorities. These discussions were aided by the background information compiled by García Borboroglu and Boersma (2013), Trathan et al. (2015), and the IUCN SSC PSG during a workshop in Cape Town, South Africa (September 2016) (Boersma et al. 2017; IUCN SSC PSG 2017).

We used a modified pairwise ranking approach to prioritize the identified needs (e.g. Thurstone 1927; Kendall & Babington Smith 1940; Jones 1995). First, we each used the criteria of “general importance to penguins” to conduct pairwise comparisons, giving a vote to the need considered higher priority in each pairing. We then tallied our votes and calculated weighted scores by dividing the number of votes given to each priority by the total number of votes available. As a group, we decided which species each priority applied to (Table S2). For the final rankings, we multiplied the weighted scores by the number of relevant species (Table 2). Therefore, the highest ranked threats were those that were given the most votes as generally important to penguins and were considered relevant to all or most penguin species.
During our discussions, we acknowledged that the species facing the greatest number of conservation and research needs may not necessarily be the species of the most immediate conservation concern. Therefore, we also voted on which species were in most pressing need of policy intervention and international collaboration, using rapid population declines and/or extremely limited geographic range as our criteria. The three species that gained a unanimous vote as international priorities were:

*African Penguins* – The global population of African penguins is ca. 21,000 pairs, a decrease from over 1.5 million pairs in the early 1900s (Crawford et al. 2011). The ongoing rapid decline of African penguin populations is primarily caused by fewer prey (Crawford et al. 2011), attributable to climate change and fisheries competition (Pichegru et al. 2012; Sherley et al. 2017). Additional threats include petroleum discharge (Fowler et al. 1995; Barham et al. 2007; Wolfaardt et al. 2008), ship-to-ship bunkering (South African Department of Environmental Affairs and South African National Parks, unpubl. data), and predation by seals and land-based predators (Weller et al. 2016; Cape Nature Conservation and South African National Parks unpubl. data). An ecosystem-based approach to fisheries management that ensures sufficient prey for African penguins, especially when prey stocks are low, is urgently needed. The recently expanded Marine Protected Area (MPA) network includes some breeding colonies (Department of Environmental Affairs 2018), but it does not provide the protection necessary for all penguin life stages (Harding 2013; Roberts 2016; Sherley et al. 2017).
**Galápagos Penguins** – The Galápagos penguin is the rarest penguin species, restricted to Ecuador’s Galápagos Islands. Its population undergoes extreme fluctuations and is of unknown size due to low and variable resighting rates (Boersma et al. 2013). Galápagos penguins do not breed when food is scarce, instead spending much of their time foraging at sea. When they do breed, and often when they molt, they are hidden in lava nests where they cannot be seen (Boersma 1978). This population is threatened by severe El Niño events, which increase adult and juvenile mortality and result in breeding failure (Boersma 1978, Boersma 1998; Vargas et al. 2006), and these extreme events are becoming more frequent (Cai et al. 2014). When food is abundant, erosion of existing nesting sites, a lack of well-shaded breeding sites, and the presence of invasive predators (e.g. cats, rats) limit successful breeding and population recovery. Removing invasive predators and building predator-free breeding sites would benefit the breeding population. Given the population’s sensitivity to environmental variability, management should make use of the precautionary principle by taking actions to protect the population even in the absence of complete scientific understanding. Improving and enforcing fisheries management is crucial to ensure food availability in this variable environment; < 1% of the Galápagos Marine Reserve is closed to fishing (Moity 2018).

**Yellow-eyed Penguins** – The total population of Yellow-eyed penguins (*Megadyptes antipodes*) is estimated to be approximately 1,700 pairs (Seddon et al. 2013) and is divided into two geographically and genetically distinct management units (<40% on the South Island of New Zealand, >60% on the sub-Antarctic Campbell and Auckland Islands: Boessenkool et al. 2009). There are ongoing and projected continuation of steep declines of
the mainland populations. Declines are poorly understood but likely driven by introduced predators, diseases, environmental change, and interactions with fisheries (Alley et al. 2017; Gartrell et al. 2017; Mattern et al. 2017). Sub-Antarctic breeding areas are the population stronghold for this species, but basic research on population sizes and trends is lacking, and these populations are threatened by introduced mammals (Challies 1975). Increasing penguin-focused tourism has increased stress and reduced productivity for Yellow-eyed penguins (e.g. French et al. 2018) and may contribute to disease outbreaks. Of highest priority is developing effective marine spatial planning and tourism planning in the region.

**Conservation and Research Needs for All Penguins**

The highest-ranked research needs for penguins are related to continued population monitoring (estimating demographic rates and population trends) and to understanding environmental conditions and change. We also identified research priorities for emerging or growing threats to penguins. For example, disease surveillance is increasingly important for several penguin species, particularly for small populations that regularly come into contact with humans through tourism (e.g. spread of zoonotic enteric bacteria: Cerdà-Cuéllar et al. 2019). Diseases are a documented concern for five species of penguin (African penguins: Parsons & Vansstrels 2016; Gentoo penguins Pygoscelis papua: Munro 2007; King penguins Aptenodytes patagonicus: Cooper et al. 2009; Northern rockhopper penguins Eudyptes moseleyi: Jaeger et al. 2018; Yellow-eyed penguins: Alley et al. 2004; 2017). Other threats that are likely to be underestimated and require additional research include the impacts of
bycatch (e.g. across penguins: Crawford et al. 2017), plastic ingestion (e.g. in Magellanic penguins: Marques et al. 2018), and invasive species (e.g. across seabirds: Spatz et al. 2017).

Producing and implementing marine spatial plans (Ehler & Douvere 2009) emerged as the highest ranked conservation priority. Marine Spatial Planning (MSP) is a practical approach to ecosystem-based management (e.g. in South Africa: Lombard et al. 2019) that examines all interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation (Ehler & Douvere 2009). For penguins, this process should identify stakeholders to help map and resolve conflicts and incorporate conventional fisheries management tools, seasonal fisheries closures, and corridors that include migratory routes (e.g. Trathan et al. 2014).

Among the other conservation needs, some were restricted to a few species but represent important gaps in knowledge and/or conservation. For example, penguins at some colonies can face high rates of predation on land (e.g. goanna *Varanus rosenbergi* and cat *Felis catus* attacks on Little penguins *Eudyptula minor*: Colombelli-Négre & Tomo 2017) or at sea (e.g. seal predation on African penguins: Weller et al. 2016). Threats to penguins can be manifested in several ways. For example, climate-associated reductions and shifts in ocean productivity and prey will likely affect all species (Bost et al. 2015; Trathan et al. 2015; Ramirez et al. 2017), but climate change also has region- and/or species-specific effects. Documented effects to date include: increasing intensity and severity of El Niño–Southern Oscillation (ENSO) events affecting penguin breeding and body condition (Galápagos penguins: Boersma 1978; 1998), foraging efficiency and success (Little penguins: Pelletier et

**Leveraging Science for Penguin Conservation**

Penguins are comparatively well-studied seabirds with some of the most intensely researched breeding colonies in the ecological literature (e.g., ongoing long-term research programs: Richdale 1957; Ainley et al. 1983; Crawford et al. 2006; Boersma 2008; Chiaradia et al. 2010; Robertson et al. 2014; Barbraud et al. 2015; Bost et al. 2015). Why, then, has science not always been translated into effective conservation? We outline four areas for improvement.

First, understanding penguins requires long-term datasets, but long-term datasets are rare, usually localized, and often spearheaded by a small number of individuals working independently. Adding to this, it is difficult to find funding for long-term studies (Birkhead 2014; Kuebbing et al. 2018). As is the case for several institutions (e.g. the Antarctic Ecosystem Research Division: Trivelpiece et al. 2011; Hinke et al. 2015; the Australian Antarctic Division: Emmerson & Southwell 2008; Southwell et al. 2017; the French Polar
Institute: Jenouvrier et al. 2014; Bost et al. 2015), all governmental institutions should strive to maintain long-term research that go beyond tracking abundance, i.e. that includes monitoring of ecological processes and other information key to effective penguin conservation.

Second, it is easiest and least expensive to study penguins during the breeding season, when they are central place foragers. For example, over 75% of the penguin tracks in BirdLife International’s Seabird Tracking Database occurred during the breeding season (BirdLife International 2018). However, the non-breeding season is often marked by increased mortality compared to the breeding season (e.g. in Northern rockhopper penguins and Southern rockhopper penguins *Eudyptes chryso come*: Dehnhard et al. 2013) and can have effects that carry over to the next breeding season (e.g., African penguins: Sherley et al. 2013; Little penguins: Salton et al. 2015; Magellanic penguins: Rebstock & Boersma 2018; Northern and Southern rockhopper penguins: Thiebot et al. 2012; Macaroni penguins *Eudyptes chrysolophus*: Crossin et al. 2010).

In the non-breeding season, some penguin species migrate thousands of kilometers and our knowledge of these movements remain limited (e.g., Magellanic penguins: Stokes et al. 2014; Fiordland penguins *Eudyptes pachyrhynchus*: Mattern et al. 2018; Table 1). There is especially little knowledge of juvenile life stages, as juvenile penguins often prospect at other colonies and remain unobservable at their natal colony for the first few years after fledging or, in some cases, emigrate permanently (e.g. Humboldt penguins: Simeone and Wallace 2014; Magellanic penguins: Stokes et al. 2014). Improved knowledge of this stage is key to
conservation because some penguin species have low juvenile survival rates (e.g. <20% on average for African penguins: Sherley et al. 2018 and Magellanic penguins: Gownaris & Boersma 2019; but >75% for King penguins: Saraux et al. 2011 and Southern rockhopper penguins: Dehnhard et al. 2014), which can be strong drivers of population decline (e.g., in Magellanic penguins: Gownaris & Boersma 2019). Some penguins, such as those in remote regions of Antarctica and the sub-Antarctic or in the sea caves or coastal forests of New Zealand, are challenging to study year-round for all life stages. Growing use of technology, such as satellite imagery, may help to better study colonies in remote locations (Ancel et al. 2017; Borowicz et al. 2018).

Third, although reproductive success shows a more immediate and dramatic response to improved resource availability (Oro 2014), penguin population growth rates are most sensitive to changes in adult mortality (e.g., in African penguins: Sherley et al. 2018; in Magellanic penguins: Gownaris & Boersma 2019), requiring adaptive management and protection at broader spatial and temporal scales. Most penguin species forage over large areas (e.g. Boersma & Parrish 1999; Bost et al. 2015; Mattern et al. 2017) that vary between the breeding and non-breeding season (Warwick-Evans et al. 2018) and sometimes with age class (Sherley et al. 2017). Foraging areas may extend to internationally managed waters and often cross jurisdictional boundaries (e.g. see BirdLife International 2018 for tracking data). Safeguarding the future of penguins will therefore require international collaboration on spatial planning, particularly in areas beyond national jurisdiction (Trathan et al. 2018; Warwick-Evans et al. 2018). Both the Convention on Biology Diversity (2010) and the United Nations (2015) have set ocean protection targets of 10% by 2020. Most recently,
IUCN (2016) members approved a global target of protecting 30% of the world's oceans by 2030. Although there has been progress towards reaching these goals at a global level, still only 2% of the ocean is strictly or fully protected (Sala et al. 2018).

Marine reserves are not a panacea for fisheries management problems. However, when guided by a case-by-case understanding of fisheries and ecosystem structure, they can be valuable tools for conservation (Hilborn et al. 2004). Experimental fishing closures surrounding breeding colonies of African penguins, for example, demonstrated reduced effort by breeding birds during foraging (Pichegru et al. 2010), increased breeding success (Sherley et al. 2015; 2018), and improved chick condition (Sherley et al. 2018). These effects were observed despite concerns surrounding the closures, including: displacement of fishing effort (Pichegru et al. 2012), appropriateness of the experimental design (Weller et al. 2014), and spatial (Pichegru et al. 2012) and temporal (Crawford et al. 2013) resolution.

Finally, scientific data are necessary but, in many cases, insufficient to motivate effective conservation action (Ropert-Coudert at al 2019). Improving science communication to decision makers and key stakeholders is also required. For example, at a Population and Habitat Viability Assessment workshop for Humboldt penguins (Araya et al. 1999), there were intensively conflicting points of view between researchers and fisheries managers. Biologists were concerned that being overly optimistic would lead to the decline or extinction of Humboldt penguins, while fisheries managers worried that being overly pessimistic would lead to the collapse of fisheries (Araya et al. 1999). Despite these conflicting points, this workshop was crucial in defining research priorities that considerably improved the type and
quality of data obtained for the Humboldt penguin in the following decades (e.g. Paredes et al. 2003).

In other examples, decades of research on Magellanic penguins (Boersma et al. 2009; Boersma & Rebstock 2009) led to recommendations for the boundaries of a marine reserve (Boersma et al. 2015). However, the science itself did not catalyze conservation action until further efforts were made to engage politicians, legislators, and key stakeholders (García Borboroglu et al. 2015). Similarly, the Biodiversity Management Plan for the African penguin is based on a long history of research (e.g. Crawford et al. 2011) and resulted from collaboration and active engagement among scientists, managers, NGOs, and legislators (Department of Environmental Affairs, 2013). In the South Indian Ocean, collaboration between scientists and politicians led to the expansion of the marine reserve surrounding the Kerguelen and Crozet archipelagoes (TAAF Nature Reserve; TAAF 2016). This expansion included the creation of a large no-take zone (120,000 km²), which benefits many marine predators, penguins included. Elsewhere in the South Indian Ocean, tracking of Northern rockhopper and other seabird species support the recent expansion of the Amsterdam Island marine reserve, which now covers the island’s entire EEZ (Heerah et al. 2019). These examples show that individual scientists and interdisciplinary species-specific working groups play important roles as experts on and advocates for the species they study (IUCN 2017). They also highlight that success depends on establishing trustful lines of communication with decision-makers.
Penguins are found in most of the southern hemisphere’s biodiversity hotspots (Ramírez et al. 2017) and act as marine sentinels (e.g. “canaries in the coal mine”) in these systems (Boersma 2008). The general decline in the population size of many penguin species warns us about the widespread ecological changes underway across the suite of habitats used by penguins and highlights the need for immediate and focused conservation efforts in marine and terrestrial systems alike. Penguins are long-lived and often disperse widely during the non-breeding season, characteristics at odds with the current approach to conservation: short-term funding, small-scale spatial protection, and the lack of effective, internationally coordinated management. Conserving penguins will require creativity, collaboration, and commitment among diverse stakeholders. In this essay, the IUCN SSC PSG highlights systematically identified research and conservation priorities to move this agenda forward. By fostering communication of and policy action towards these priorities, our goal is to help ensure that wild penguins exist in perpetuity.

Acknowledgments

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Supporting Information
Supporting Information 1 details the affiliations and expertise of the Penguin Specialist Group of the IUCN’s Species Survival Commission. Supporting Information 2 provides descriptions and examples of each conservation and research priority. Supporting Information 3 contains a table showing whether each conservation and research priority was needed for the 18 species of penguin.

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### Tables

**Table 1: Basic Information on the Eighteen Species of Penguin**

<table>
<thead>
<tr>
<th>Species</th>
<th>IUCN status 2013</th>
<th>IUCN status 2018</th>
<th>Population trend (IUCN 2018)</th>
<th>Main breeding colonies &amp; foraging range</th>
<th>Maximum recorded non-breeding range (one-way)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emperor (<em>Aptenodytes forsteri</em>)</td>
<td>NT</td>
<td>NT</td>
<td>Unknown</td>
<td>Polar</td>
<td>~ 7,000 km (juveniles; Wienecke et al. 2010)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&gt; 1,000 km (adults; Kooyman et al. 2004)</td>
</tr>
<tr>
<td>King (Pygoscelis antarctica)</td>
<td>LC</td>
<td>LC</td>
<td>Increasing</td>
<td>Sub-Antarctic</td>
<td>2,650 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Orgeret &amp; Bost, unpubl. data)</td>
</tr>
<tr>
<td>Adélie (Pygoscelis adeliae)</td>
<td>NT</td>
<td>LC</td>
<td>Increasing</td>
<td>Polar</td>
<td>~ 4,000 km (juveniles), ~ 3,000 km (adults)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Orgeret &amp; Bost, unpubl. data)</td>
</tr>
<tr>
<td>Chinstrap (Pygoscelis papua)</td>
<td>NC</td>
<td>LC</td>
<td>Decreasing</td>
<td>Sub-Antarctic</td>
<td>4,000 km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(Hinke et al. 2015)</td>
</tr>
<tr>
<td>Gentoo (Pygoscelis papua)</td>
<td>NT</td>
<td>LC</td>
<td>Stable</td>
<td>Sub-Antarctic</td>
<td>Unknown</td>
</tr>
<tr>
<td>Macaroni (Eudyptes chrysolophus)</td>
<td>VU</td>
<td>VU</td>
<td>Decreasing</td>
<td>Sub-Antarctic</td>
<td>~ 3,000 km</td>
</tr>
<tr>
<td>Royal (Eudyptes schlegeli)</td>
<td>VU</td>
<td>NT</td>
<td>Stable</td>
<td>Sub-Antarctic</td>
<td>Unknown</td>
</tr>
<tr>
<td>Species</td>
<td>IUCN</td>
<td>IUCN</td>
<td>Status</td>
<td>Range</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Northern rockhopper (Eudyptes moseleyi)</td>
<td>EN</td>
<td>EN</td>
<td>Decreasing</td>
<td>Sub-Antarctic</td>
<td>&gt; 2,000 (Thiebot et al. 2012)</td>
</tr>
<tr>
<td>Southern rockhopper (Eudyptes chrysocome)</td>
<td>VU</td>
<td>VU</td>
<td>Decreasing</td>
<td>Sub-Antarctic</td>
<td>~ 2,500 km (Thiebot et al. 2012)</td>
</tr>
<tr>
<td>Fiordland (Eudyptes pachyrhynchos)</td>
<td>VU</td>
<td>VU</td>
<td>Decreasing</td>
<td>Oceania</td>
<td>~ 2,500 km (Mattem et al. 2018)</td>
</tr>
<tr>
<td>Snares (Eudyptes robustus)</td>
<td>VU</td>
<td>VU</td>
<td>Stable</td>
<td>Oceania</td>
<td>Unknown</td>
</tr>
<tr>
<td>Erect-crested (Eudyptes sclateri)</td>
<td>EN</td>
<td>EN</td>
<td>Decreasing</td>
<td>Oceania</td>
<td>Unknown</td>
</tr>
<tr>
<td>African* (Spheniscus demersus)</td>
<td>EN</td>
<td>EN</td>
<td>Decreasing</td>
<td>Africa</td>
<td>Up to ~ 600 km (juveniles) (Sherley et al. 2017) Up to ~ 4,000 km (pre- and post-moulters) (Harding 2013; Roberts 2016)</td>
</tr>
<tr>
<td>Galápagos* (Spheniscus mendiculus)</td>
<td>EN</td>
<td>EN</td>
<td>Decreasing</td>
<td>South America (equatorial)</td>
<td>~150 km (Boersma, unpubl. data)</td>
</tr>
<tr>
<td>Humboldt (Spheniscus humboldti)</td>
<td>VU</td>
<td>VU</td>
<td>Decreasing</td>
<td>South America (SE Pacific)</td>
<td>~1,000 km (post-breeding adults) (Pütz et al. 2016)</td>
</tr>
<tr>
<td>Magellanic (Spheniscus magellanicus)</td>
<td>NT</td>
<td>NT</td>
<td>Stable/Decreasing</td>
<td>South America</td>
<td>~ 4,000 km (Stokes et al. 2014)</td>
</tr>
<tr>
<td>Little (Eudyptula minor)</td>
<td>LC</td>
<td>LC</td>
<td>Stable</td>
<td>Oceania</td>
<td>~ 1,000 km</td>
</tr>
<tr>
<td>Yellow-eyed* (Megadyptes antipodes)</td>
<td>EN</td>
<td>EN</td>
<td>Decreasing</td>
<td>Oceania (New Zealand)</td>
<td>~ 150 km (M. Young unpubl. data)</td>
</tr>
</tbody>
</table>

*IUCN conservation status: LC - least concern  VU - vulnerable  NT - near threatened  EN - endangered

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*Species in bold are the three species ranked as being of the most immediate conservation concern based on a vote by the Steering Committee of the International Union for Conservation of Nature Species Survival Commission Penguin Specialist Group.

Table 2: Ranked Priorities for Penguin Research and Conservation

<table>
<thead>
<tr>
<th></th>
<th>Pairwise ranking Score</th>
<th>No. Relevant Species</th>
<th>Final Weight</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RESEARCH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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