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Short communication

The impact of taxonomic change on conservation: Does it kill, can it save, or is it just irrelevant?

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ABSTRACT

The important question of taxonomy and its impact on conservation efforts was brought to general attention by Robert May in 1990 with a *News and Views* article in *Nature* entitled "Taxonomy as destiny." Taxonomy, however, has built-in instabilities that result in name changes, raising the question of whether name changes have a consistent impact on conservation efforts. Our review investigates three possible outcomes of taxonomic change, namely a positive impact on protection efforts, a hampering impact, or no measurable impact. We address these cases with a review of the relevant literature: specifically, government and conservation agency reports, scientific papers, and the general press, as well as correspondence with biologists active in plant and animal conservation. We found no evidence of a consistent effect of taxonomic change on conservation, although splitting taxa may tend to increase protection, and name changes may have the least effect where they concern charismatic organisms.

1. Introduction

The important question of taxonomy and its impact on conservation efforts was brought to general attention by Robert May in 1990 with a *News and Views* article in *Nature* entitled "Taxonomy as destiny." May commented on how an iguana-like reptile, the Brother's Island tuatara (*Sphenodon guntheri*) off the coast of New Zealand, was not recognized as a distinct species from *Sphenodon punctatus* and had therefore been ignored by protective legislation. When genetic data became available, the island's endemic population was deemed sufficiently distinct to justify special protection of its gene pool (May, 1990). The cover of the *Nature* issue was entitled "Bad taxonomy can kill" to highlight May's point. Assigning the terms good and bad to taxonomic research (or the resulting taxonomies) introduced a value-laden framework to the issue. Nevertheless, numerous papers took up the idea that "bad" taxonomy can hinder conservation (Funk et al., 2002; Gittleman and Pimm, 1991; Khuroo et al., 2007; Mace, 2004; McNeely, 2002; Russello et al., 2005). However, none appear to have addressed the definition of good and bad taxonomy. Since there are no accepted criteria for judging what is "good" taxonomy, a pragmatic approach is to consider the most recently published taxonomy, which typically will include better sampling and more genetic data, as better than the previous (old, "bad") taxonomic treatment that is being replaced on the basis of the new data.

All conservation—indeed, almost all biology—is based on taxonomy, part of which involves the proper identification of organisms. Such identification usually involves a scientific name assigned to the entity of interest, commonly a species name. No universal criteria exist for assigning taxon ranks, such as species or subspecies, or for establishing boundaries among taxa, such as between species or genera. As a result, taxonomic stability is an elusive goal, a fact well understood by systematists (Dubois, 2007; Heywood and Davis, 1963). Besides the subjectivity of ranking and circumscription, there are at least three additional causes of taxonomic instability. These are the continually improved knowledge of phylogenetic relationships, which can lead to the transfer of species names between genera, at least under a Linnean system of nomenclature (De Queiroz and Gauthier, 1990). A second cause is an increased understanding of gene flow, which could lead to lumping or splitting of taxa, even if previous circumscriptions were done objectively. A third source is the recognition of nomenclatural errors made earlier, for example, concerning priority or homonymy. These sources of taxonomic instability reflect scientific progress. Instability, therefore, is an expected outcome of active taxonomic research. Given this continuous change in taxonomic naming and classifying of organisms, it is important to know whether new ("good") taxonomies tend to positively impact conservation efforts, as implied by May's commentary or whether taxonomic change has no consistent impact on conservation efforts.

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There have been several reviews that have analyzed the number of species moving on and off of local red lists as a result of changes in taxonomy. These changes were due mainly to the adoption of narrower or wider species concepts or to the correction of nomenclatural errors (Garnett et al., 2003; Lozano et al., 2007). However, changes in status on endangered species lists often do not equate to changes in conservation efforts. In this study, we therefore focus instead on cases where taxonomic change had a direct effect on conservation funding or efforts towards monitoring and research. This may have biased us towards finding positive or negative effects, rather than no impact (see Section 4). The specific question we wanted to answer was: Are the effects of "improved" (new) taxonomies on conservation efforts consistent and hence predictable? Although our review is limited by its qualitative nature, consisting of a number of case studies, it includes a broad range of clades, from several countries, classified under a variety of conservation laws and systems. To our knowledge, this is the first attempt to objectively focus on the practical effects of taxonomic instability on conservation efforts.

2. Methods

2.1. Survey for information

We searched for species or populations on lists of threatened or endangered species whose protection had changed due to changes in taxonomic rank or circumscription. Change in protection was defined and categorized as described below. At the global level, the International Union for Conservation of Nature and Natural Resources Red List of Threatened Species (IUCN Red List; www.iucnredlist.org) and the species listed in the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) were consulted. To determine changes in conservation status at regional or local levels and/or country legislation for protected species, we searched the following databases: US Fish & Wildlife Service (USFWS), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the Species at Risk Act Registry (SARA) of Canada, the Joint Nature Conservation Committee (JNCC) of the United Kingdom, Bayerisches Landesamt für Umwelt (Bavaria State Environmental Agency, Germany), The British Columbia Conservation Data Centre (CDC) and the Missouri Species and Communities of Conservation Concern Checklist. We also looked for information in the World Wildlife Fund, the Nature Server and the Xerces Society for Invertebrate Conservation, given that these organizations are currently dealing with endangered species conservation programs. We surveyed journals focusing on conservation (*Biodiversity and Conservation*, *Biological Conservation*, *Conservation Biology*, *Conservation Genetics*, *Journal for Nature Conservation*), general journals that report on conservation (e.g., *Nature*), and we searched the databases Science Direct, Blackwell-Synergy, JSTOR and Biomed Central using the search terms "conservation status change," "taxonomic status change," and "propose change conservation," among others. Finally, we contacted experts from different branches and organizations concerned with nature conservation.

2.2. Impact of taxonomic change on conservation

Based on our initial findings and incorporating the terminology used in the 1990 *Nature* issue, we have separated our cases into three categories: (1) *taxonomy protects*, when the change had a positive effect on the conservation, for example, via increased efforts in monitoring programs; (2) *taxonomy is irrelevant*, when the change of rank or circumscription did not have any impact on the conservation status or efforts in conservation programs; and (3) *taxonomy kills*, when a taxonomic revision led to the decrease or discontinuation of conservation programs being carried out. A change in protection (conservation) was defined as increased or decreased monitoring of any kind, as well as increased or decreased funding for research on the respective organism.

3. Results

3.1. Taxonomy protects

We found numerous examples where a change in taxonomy led to increased efforts in conservation, in groups as diverse as plants, birds, frogs, dolphins, and giraffes. One example is the Chiricahua leopard frog (*Rana chiricahuensis*), whose current range is restricted to eastern Arizona in the United States (Table 1). This species was originally assigned to *Rana pipiens*, but was subsequently split into over two dozen species (Hillis, 1988), one being the Chiricahua leopard frog (Platz and Mecham, 1979). Because of the rapid extirpation of this frog from its historical range (Clarkson and Rorabaugh, 1989), the Chiricahua leopard frog was listed as threatened in 2002 under the Endangered Species Act of 1973 (ESA), whereas *R. pipiens* enjoys no special conservation status (Humphrey and Fox, 2002; Rorabaugh, 2002). In response to the listing, the Malpai Borderlands Group was formed (Glick, 2005), which is a group of private landowners and over 12 public institutions that has thus far protected over 30,350 ha of private land in the form of conservation easements.

A plant example where taxonomic change (i.e., new taxonomy, not necessarily a taxonomy arrived at by majority consensus) has led to increased protection is in the mountain ash (*Sorbus*) of central Europe. Recently, over 20 new species were described in this formerly poorly documented genus (Meyer et al., 2005; but see Aldasoro et al., 2004). All 20 are now found on the Bavarian Red List of Vascular Plants, with subsequent support for their conservation coming from the Bayerische Landesamt für Umweltschutz, the Naturpark Fränkische Schweiz, the foundation Schöpfung Bewahren Konkret, and other nature protection organizations, including several volunteer and benefactor agencies (Scheuerer and Ahlmer, 2003).

Similarly, conservation of the Ozark spring beauty (*Claytonia ozarkensis*) was beneficially affected by a taxonomic name change. This herb occurs sympatrically with congenerics in Arkansas, Missouri and Oklahoma. Specimens had been misidentified as *Claytonia virginica* or *Claytonia caroliniana* until a complete taxonomic revision of the genus resulted in the description of the new, previously overlooked species *C. ozarkensis* in 2006. This discovery triggered immediate protection efforts (Missouri Natural Heritage Program, 2009) due to the rarity of *C. ozarkensis*, which consists of only a dozen populations (G. Yatskievych, Missouri Botanical Garden, St. Louis, personal communication, 2008).

Another example of new taxonomy leading to increased conservation efforts is that of the California gnatcatcher, *Polioptila californica*. The California gnatcatcher was originally recognized as a species in 1881, but was lumped back with the black-tailed gnatcatcher (*Polioptila melanura*) half a century later because of similarities in plumage coloring (Grinnell, 1926). It was re-split from the black-tailed gnatcatcher in 1989, on the basis of distinctive song and morphology (Atwood, 1988; later confirmed by molecular studies; Zink et al., 2000). After recognition of its species status, the California gnatcatcher received greater habitat protection (from encroaching development) and better monitoring programs (Zink et al., 2000), in a variety of national and state parks (Atwood and Bontrager, 2001). As in the case of the Chiricahua leopard frog, the species from which the California gnatcatcher was split receives no special attention. Taxonomic research revealed the narrow geographic range of these species, bringing to light the need to protect them and this need was acted upon with increased conservation efforts.

Table 1
Summary of cases where changes in taxonomy either helped conservation efforts, hampered them, or were irrelevant for conservation efforts.

Name	IUCN[a] ver. 3.1 (IUCN, 2008)	Local red lists	Geographic region	Case details	Impact of taxonomy on conservation
Taxonomy protects					
Rowan/mountain ash *Sorbus* spp.	Not listed	All listed	Central Europe	Revision of *Sorbus* (Meyer et al., 2005), led to many new species receiving attention from local protection agencies	Increased conservation
Scurvy-Grass *Cochlearia bavarica* (Vogt, 1985)	Not listed	Highly endangered	Southern Bavaria	Chromosome and morphological analysis led to description of *C. bavarica* as new sp. in 1985	Increased conservation
California gnatcatcher *Polioptila californica* (Brewster, 1888)	Least concern	Least concern	California	Subspecies which gained full species status in 1989 (Zink et al., 2000)	Increased conservation
Chiricahua leopard frog *Rana chiricahuensis* (Platz and Mecham, 1979)	Vulnerable	Threatened	Arizona	Genetically distinct from *R. pipiens* (Platz and Mecham, 1979), which has no special conservation status in the USA)	Increased conservation
Spring beauty *Claytonia ozarkensis* (Mill and Chambers, 1993)	Not listed	Critically imperiled	Arkansas west to Oklahoma	Described as new species in 2006 (Miller and Chambers, 2006)	Increased conservation
Rockey mountain tailed frog *Ascaphus montanus* (Nielson et al., 2001)	Least concern	Endangered in Canada	BC along the Rocky Mountains, into Montana	Split from *A. truei* based on molecular evidence (Carstens et al., 2005; Nielson et al., 2001)	Increased conservation
Pink River Dolphin *Inia boliviensis* (d'Orbigny, 1834)	Data deficient	Data deficient	Amazon	Genetic data strongly indicate the existence of a separate gene pool/species in Bolivia (Banguera-Hinestroza et al., 2002)	Increased conservation
Taxonomy is irrelevant					
Lapland marsh-orchid *Dactylorhiza lapponica* (Laest. ex Hartm) Soó	Not listed	Delisted	British Isles	Synonymized under *D. traunsteineri*, a more frequent species (Bateman, 2001). *D. lapponica* lost status as threatened sp.	No change
Galápagos Sea Lion *Zalophus wollebaeki* (Sivertsen, 1953)	Endangered	Galápagos endemics are protected	Galápagos archipelago	Species status validated with molecular data (Wolf et al., 2007). It has experienced population size decrease in the last 30 years	No change
West African Giraffe *Giraffa camelopardalis peralta* (Linnaeus, 1758)	Least concern	Critically endangered	Niger	Genetic evidence points to another sp. or ssp. not represented in zoos and losing habitat in west Africa	No change
Polar Bear *Ursus maritimus* (Phipps, 1774)	Vulnerable	Federally threatened	Circumpolar	Genetic evidence: this sp. is this species is poorly distinct from brown bears (Talbot and Shields, 1996a,b)	No change
Red Wolf *Canis rufus* (Audubon and Bachman, 1851)	Critically endangered	Endangered	Southeast USA	Genetic data shows that this is a form of the Gray Wolf, *C. lupus* (Wilson and Reeder, 2005)	No change
Marbeled Murrelet *Brachyramphus marmoratus* (Gmelin, 1789)	Endangered	Endangered	Pacific Northwest	There are actually five sp. (Friesen et al., 2005); Petition filed in May 2008 to remove the sp. from the endangered wildlife list; action is under review	No change
Ramsey canyon leopard frog *Rana subaquavocalis* (Platz, 1993)	Critically endangered	Protected by local conservation agreements	SE Arizona	*R. subaquavocalis* genetically indistinguishable from *R. chiricahuensis* (Goldberg et al., 2004)	No change
Green Sea turtle *Chelonia mydas* (Bocourt, 1868)	Endangered	Threatened	East-Pacific, but range unclear	No genetic distinction between *C. agassizii* and *C. mydas* (Karl and Bowen, 1999)	No change
Taxonomy kills					
Dusky seaside sparrow *Ammodramus maritimus nigrescens* (Ridgway, 1873)	Extinct	Not listed	Florida	Species status removed in 1973, along with protection. The subspecies was declared extinct in 1990 (Rising, 2005)	Decreased conservation
Lloyd's hedgehog cactus *Echinocereus lloydii* (Britton and Rose, 1922)	Not listed	Delisted in 1999	Texas and New Mexico	Was a hybrid between *E. coccineus* and *E. dasyacanthus* (Powell et al., 1991)	Decreased conservation
Cape Verde kite *Milvus milvus fasciicauda* (Hartert, 1914)	Not listed	Not listed	Cape Verde archipelago	Not genetically distinct (Johnson et al., 2005). No protection given to the subspecies	Decreased conservation
Idaho springsnail *Pyrgulopsis idahoensis* (Pilsbry, 1933)	Data deficient	Nationally endangered but recently delisted	SW Idaho	Listed in 1992 as endangered sp., but delisted in 2007. Reason: this sp. should be grouped with *Pyrgulopsis robusta* (Hershler and Liu, 2004), a sp. with a much greater range	Decreased conservation
Mitchell's satyr butterfly *Neonympha mitchellii mitchellii* (French, 1889)	Not listed	Nationally endangered	SW Michigan and N Indiana	New pops found in AL, MS and VA, but actually of the ssp. *N. francisci francisci*; lost conservation status since this is not an endangered species (Goldstein et al., 2004)	Decreased conservation (for new populations)

[a] International Union for Conservation of Nature Red List 2008: http://www.iucnredlist.org/.

All the above cases have one common thread: they represent species that have been subdivided, with the more narrowly circumscribed entities then afforded increased protection.

3.2. Taxonomy is irrelevant

We found at least five situations where conservation efforts ignore taxonomic changes. First, there is the case of charismatic organisms. An example of a charismatic animal is the red wolf (*Canis rufus*), a highly endangered mammal with remaining populations in small regions of the US and Canada (Nowak, 2002, 2003). The species status of the red wolf has been a matter of debate, with some workers viewing it as a distinct species, others as a hybrid between the grey wolf (*Canis lupus*) and the coyote (*Canis latrans*; Wayne and Jenks, 1991). Further molecular analyses suggest that the red wolf is a subspecies of *C. lupus* (Murray and Waits, 2007). As far as we could ascertain, these changes have not changed conservation efforts or monitoring and reintroduction programs (USFWS, 2007b).

A similar case is the polar bear (*Ursus maritimus*). Several phylogenies of Ursidae, based on mitochondrial and nuclear DNA, increasingly suggests that polar bears and brown bears (*Ursus arctos*) are not mutually monophyletic (Talbot and Shields, 1996a, 1996b; Waits et al., 1999). This may mean that the polar bear is not a biological species, a fact that could hinder conservation efforts. Nevertheless, after a 3-year long review, the USFWS made its final ruling in 2008 that the polar bear is a threatened species (Schliebe and Johnson, 2008). This has led to continued monitoring and conservation activities among assorted institutions (USFWS, 2008). However, the real threat for the polar bear now is climate change (Williams, 2009).

Another example of a charismatic animal that has received continued protection despite changed taxonomy is the green turtle (*Chelonia mydas*). This sea turtle had been considered an endangered species since 1982 due to decreasing population sizes (IUCN). In 1999, a molecular study indicated no significant distinction between the green turtle and the black turtle (*Chelonia agassizii*; Karl and Bowen, 1999), and as a result *Chelonia mydas* and *C. agassizii* are now treated as a single species (NMFS and USFWS, 2007). However, a monitoring program for the green turtle was started in Mozambique in 2004 by the WWF Homeland Foundation-USA and represents an investment of $210,000 USD (www.wwf.org.mz). Despite the fact that the taxonomy of black and green turtles remains doubtful, monitoring and protection have been maintained continuously.

The second situation where conservation decisions ignore taxonomic changes concerns certain areas and ecosystems of the world that are protected and, therefore, everything living within those areas receives conservation status, regardless of taxonomic name changes. One such ecosystem is the Galápagos archipelago, and the example animal is the Galápagos sea lion (*Zalophus wollebaeki*). Until recently, this sea lion was considered a subspecies of the Californian sea lion (*Zalophus californicus*), which has a different demography and conservation status. In 2006, an analysis of mitochondrial and nuclear DNA markers showed that the Galapagos sea lion is a separate species (Wolf et al., 2007). However, monitoring and conservation actions have not been affected by the taxonomic change (Alava and Salazar, 2006; CDF, 2006).

A third case of conservation efforts consciously ignoring taxonomy (at least low-level taxonomies) involves endangered groups that receive blanket protection, for example, Orchidaceae. The lapland marsh-orchid (*Dactylorhiza lapponica*), which occurs in sloping fens throughout Europe, has received conservation attention in the British Isles due to habitat loss and degradation. It was included in Schedule 8 of the Wildlife and Countryside Act, 1981 (JNCC, 2008), giving it additional protection. However, morphological and molecular studies have shown that individuals from the British Isles belong to *Dactylorhiza traunsteineri,* a common European species (Bateman, 2001). Consequently, *D. lapponica* has lost its threatened status (Cheffings and Farrell, 2005). Regardless of this taxonomic lumping, its collection remains highly restricted as it is included in Appendix II of CITES, which lists species that are not currently threatened with extinction but that may become so unless trade is controlled.

Organisms with economic value are a fourth case where taxonomic change is irrelevant to conservation efforts. An example are marine stocks such as salmon, tuna, oysters, and anchovies; taxonomic work on these animals focuses on identifying genetically distinct stock lines for creating guidelines and quotas. In the case of salmon, there was a push to identify wild strains that could qualify for wildlife protection under the ESA act (Allendorf and Waples, 1996; National Research Council, 1996).

3.3. Taxonomy kills

Cases where taxonomic change (i.e., new "good" taxonomy) resulted in less protection for populations concerned species that were lumped with another, typically becoming a subspecies or variety. The larger group then has a greater range, resulting in decreased conservation efforts for the subspecies. This was the case for the Idaho spring snail (*Pyrgulopsis idahoensis*), with a range limited to the Snake River in Idaho, USA (Hershler, 1994). In 1992, *P. idahoensis* was listed under the ESA as endangered (Duke, 1992), followed by recovery plans by the USFWS to restore habitat along the Snake River as well as ensure self-sustaining breeding populations of *P. idahoensis* (USFWS, 1995). However, new genetic evidence emerged in 2004, after which *P. idahoensis* was grouped with *Pyrgulopsis robusta* (Hershler and Liu, 2004). As a result, the USFWS removed *P. idahoensis* from the endangered list (USFWS, 2007a), which has resulted in decreased monitoring efforts (USFWS, 2007c).

The dusky seaside sparrow (*Ammodramus maritimus nigrescens*), declared extinct in 1990, is another case where a species was lumped within another larger species. This passerine bird's extinction was due to loss of habitat in the salt marshes of Florida, USA (Walters, 1992). The dusky seaside sparrow was ranked as a species, *Ammospiza nigrescens*, until 1973 when the American Ornithologists' Union (AOU) Checklist Committee lumped it with the seaside sparrow (AOU, 1973; Rising, 2005). The seaside sparrow has a much larger range and is a species of least concern. In the 1980s, there were petitions for protection of the duskies and for according them species status. However, by 1990, the dusky seaside sparrow was extinct (Walters, 1992; Rising, 2005).

Another case where new taxonomic insights (and following name changes) can result in less protection concerns hybrids, which are not protected under conservation acts and laws. Lloyd's hedgehog cactus (*Echinocereus lloydii*) was listed as endangered in 1983 due to threats from over-collection and highway projects in the state of Texas (Poole and Riskind, 1987). However, data from morphology, cytology and experimental hybridization revealed that *E. lloydii* was a hybrid between *Echinocereus coccineus* and *Echinocereus dasyacanthus* (Powell et al., 1991). Accordingly in 1999 Lloyd's hedgehog cactus was removed form the Federal List of Endangered and Threatened Plants, thereafter receiving less habitat protection (Kennedy, 1999).

4. Discussion

Our findings show that the phrase "bad taxonomy can kill," coined by the editorial staff of Nature (1990) and used widely since

(Funk et al., 2002; Gittleman and Pimm, 1991; Khuroo et al., 2007; Mace, 2004; McNeely, 2002; Russello et al., 2005), does not adequately describe how taxonomic research affects conservation. It implies that good (new) taxonomies will generally help the protection of organisms, while bad (old) classifications will generally harm conservation efforts. Instead we found that changes in taxonomy do not have consistent and predictable impacts on conservation. Nevertheless, there are some general trends: (i) All of the examples where taxonomic change helped protection involve splitting (Table 1: Chiricahua leopard frog, Ozark spring beauty, *Sorbus*). (ii) Taxonomic change has least impact on the protection of iconic or charismatic organisms, protected areas of special status, and economically important groups. And finally (iii), taxonomic progress can be detrimental to conservation when it involves species amalgamation (lumping) or reveals the hybrid nature of a species.

It has been suggested that a phylogenetic species concept may encourage up-ranking of varieties or subspecies to species, perhaps by up to 48% (Agapow et al., 2004). This may cause taxonomic inflation, a loaded term for what others see as the much-needed incorporation of evolutionary research into taxonomy (Isaac et al., 2004; Knapp et al., 2005). The use of species lists in legislation and fundraising may also have created non-biological forces that favor splitting over lumping (Karl and Bowen, 1999; Meiri and Mace, 2007; Padial and De La Riva, 2006). Splitting carries the added allure of associating the author's name with the newly described taxon. However, when Padial and De La Riva (2006) looked at the number of amphibian subspecies up-ranked to, or demoded from, species rank between 1980 and 2004, they found no definite trend and concluded that rank changes reflected random fluctuations in taxonomic effort. Their paper also graphed a large upsurge in taxonomic splits, beginning in the 1950s (their Fig. 3), suggestive of a pervasive trend in herpetology away from recognizing subspecies and toward recognizing allospecies of a superspecies. There do not appear to be data from other groups on whether taxonomic change is becoming biased towards splitting or if there is an increased willingness of taxonomists to split for conservation purposes.

As pointed out by others (e.g., Leme, 2003), lumping of taxa can lead to purely nominal extinctions. However, when errors are made in synomymizing names, nominal extinctions lead to real extinctions if species are delisted as a result, with subsequent cessation in monitoring and policy efforts for their protection. Our example of the dusky seaside sparrow is the only example we found of such a nominal extinction having turned into a real extinction. Conversely, there can be nominal resurrections where species considered extinct are reborn through taxonomic research (e.g., *Melospiza melodia graminea*, endemic to islands off the coast of southern California; Patten and Pruett, 2009). If the resurrected taxon has a restricted range and is at risk, then conservation actions might result, leading to another example of "good taxonomy can protect."

Since our literature search was focused on finding cases where taxonomic change had a direct effect on conservation efforts, our results may be biased towards positive or negative effects, rather than no impact. Even so, we found many examples of taxonomic change being irrelevant to conservation efforts (e.g., red wolf, polar bear, green turtle, which may not be biological species, yet are actively protected). This illustrates that conservation efforts often (?) disregard taxonomic research. Populations valued by humans, for whatever reason – charisma, beauty, or economic worth – are protected regardless of their taxonomic rank. This fits with conservation, like taxonomy, being strongly biased towards particular clades. In a review of 2700 conservation-focused articles, vertebrates were the focus of 69%, yet contribute only about 3% of the species on Earth (Clark and May, 2002).

A limitation of our review is that it is only qualitative; yet to our knowledge, this is the first attempt to compile information on whether taxonomic change has a consistent (positive or negative) effect on conservation efforts. Our failure to pick up any consistent relationship between revised taxonomic views and conservation efforts suggests that the positive and negative effects of taxonomic change on conservation efforts may balance each other. A question for a future metaanalysis would be if different species concepts in the different taxonomic sub-disciplines have influenced conservation measures for those organisms. If specialists in a given group tended to accept narrower species, with their attendant smaller ranges, they might unintentionally help their taxon's conservation.

It is important to remember, however, that taxonomy has many functions besides helping biodiversity conservation. Taxonomy is the basis for communicating about organisms. Moreover, it is important for medicine and human health (Utevsky and Trontelj (2005) for a striking example). And, while taxonomic change may have no predictable effects on conservation, a better understanding of evolutionary relationships, resulting from taxonomic research, is always an important addition to our knowledge about the organisms that we want to protect.

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References

Agapow, P.M., Bininda-Edmonds, O.R.P., Crandall, K.A., Gittleman, J.L., Mace, G.M., Marshall, J.C., Purvis, A., 2004. The impact of the species concept on biodiversity studies. Quart. Rev. Biol. 79, 161–179.

Alava, J.J., Salazar, S., 2006. Status and conservation of otarrids in Ecuador and the Galápagos Islands. In: Trites, A.W., DeMaster, D.P., Fritz, L.W., Gelatt, T.S., Rea, L.D., Wayne, K.M. (Eds.), Sea Lions of the World. Alaska Sea Grant Program, pp. 495–520.

Aldasoro, J.J., Aedo, C., Garmendia, F.M., de la Hoz, F.P., Navarro, C., 2004. Revision of *Sorbus* subgenera *Aria* and *Torminaria* (Rosaceae-Maloideae). Syst. Bot. Monogr. 69, 1–148.

Allendorf, F.W., Waples, R.S., 1996. Conservation genetics of salmonid fishes. In: Avise, J.C., Hamrick, J.L. (Eds.), Conservation Genetics: Case Histories from Nature. Chapman and Hall, New York, pp. 238–280.

AOU, 1973. Thirty-second supplement to the American Ornithologists Union checklist of North American birds. Auk 90, 411–419.

Atwood, J.L., Bontrager, D.R., 2001. California gnatcatcher (*Polioptila californica*). In: Poole, A., Gill, F. (Eds.), The Birds of North America, No. 574. Philadelphia, Pennsylvania, USA.

Banguera-Hinestroza, E., Cardenas, H., Ruiz-Garcia, M., Marmontel, M., Gaitan, E., Vazquez, R., Garcia-Vallejo, F., 2002. Molecular identification of evolutionarily significant units in the Amazon river dolphin *Inia* sp. (Cetacea: Iniidae). J. Hered. 93, 312–322.

Bateman, R.M., 2001. Evolution and classification of European orchids: insights from molecular and morphological characters. J. Europ. Orchid. 33, 33–119.

Carstens, B.C., Brunsfeld, S.J., Demboski, J.R., Good, J.M., Sullivan, J., 2005. Investigating the evolutionary history of the Pacific Northwest mesic forest ecosystem: hypothesis testing within a comparative phylogenetic framework. Evolution 59, 1639–1652.

CDF, 2006. Sea Lion Monitoring and Conservation: Featured Projects. Charles Darwin Foundation, Puerto Ayora, Ecuador.

Cheffings, C.M., Farrell, L., 2005. The Vascular Plant Red List for Great Britain. Joint National Conservation Committee, Species Status, Peterborough, Great Britain, pp. 1–116.

Clark, J.A., May, R.M., 2002. Taxonomic bias in conservation research. Sci., New Ser. 297, 191–192.

Clarkson, R.W., Rorabaugh, J.C., 1989. Status of leopard frogs (*Rana pipiens* complex: Ranidae) in Arizona and California. Southwestern Naturalist 34, 531–538.

De Queiroz, K., Gauthier, J., 1990. Phylogeny as a central principle in taxonomy: phylogenetic definitions of taxon names. Syst. Zool. 39, 307–322.

Dubois, A., 2007. Phylogeny, taxonomy, and nomenclature: the problem of taxonomic categories and nomenclatural ranks. Zootaxa 1519, 27–58.

Duke, S.D., 1992. Endangered and Threatened Wildlife and Plants; Determination of Endangered or Threatened Status for Five Aquatic Snails in South-central Idaho. Unites States Fish and Wildlife Service, Federal Register, Rules and Regulations, pp. 59244–59257.

Friesen, V.L., Birt, T.P., Piatt, J.F., Golightly, R.T., Newman, S.H., Herbert, P.N., Congdon, B.C., Gissing, G., 2005. Population genetic structure and conservation of the marbled murrelets (*Brachyramphus marmoratus*). Conserv. Genet. 6, 607–614.

Funk, V.A., Sakai, A.K., Richardson, K., 2002. Biodiversity: the interface between systematics and conservation. Syst. Biol. 51, 235–237.

Garnett, S.T., Crowley, G.M., Stattersfield, A.J., 2003. Changes in the conservation status of Australian birds resulting from differences in taxonomy, knowledge and the defintions of threat. Biol. Conserv. 113, 269–276.

Gittleman, J.L., Pimm, S.L., 1991. Conservation biology – crying wolf in North-America. Nature 351, 524–525.

Glick, D., 2005. Back from the brink. Smithson. Mag., pp. 1–9. <http://www.smithsonianmag.com/science-nature/bring.html?c=z&page=1>.

Goldberg, C.S., Field, K.J., Sredl, M.J., 2004. Mitochondrial DNA sequences do not support species status of the Ramsey canyon leopard frog (*Rana subaquavocalis*). J. Herp. 38, 313–319.

Goldstein, P.Z., Hall, S., Hart, B., Roble, S., Shuey, J., 2004. Evaluation of Relationships and Conservation Status within the *Neonympha mitchellii* Complex (Lepidoptera: Nymphalidae). Report to United States Fish and Wildlife Service, Raleigh, NC, USA.

Grinnell, J., 1926. A critical inspection of the gnatcatchers of the Californias. Proc. Natl. Acad. Sci. USA 15, 493–500.

Hershler, R., 1994. A review of the North American freshwater snail genus *Pyrgulopsis* (Hydrobiidae). Smithson. Contr. Zool. 32, 1–41.

Hershler, R., Liu, H.P., 2004. Taxonomic reappraisal of species assigned to the North American freshwater gastropod subgenus *Natricola* (Rissooidea: Hydrobiidae). Veliger 47, 66–81.

Heywood, V.H., Davis, P.H., 1963. Principles of Angiosperm Taxonomy. Oliver and Boyd, Edinburgh and London.

Hillis, D.M., 1988. Systematics of the *Rana pipiens* complex: puzzle and paradigm. Ann. Rev. Ecol. Syst. 19, 39–63.

Humphrey, J., Fox, V., 2002. U.S. Fish and Wildlife Service Lists Chiricahua Leopard Frog as a Threatened Species. Arizona Ecological Services Field Office, Phoenix, USA.

Isaac, N.J.B., Mallet, J., Mace, G.M., 2004. Taxonomic inflation: its influence on macroecology and conservation. Trends Ecol. Evol. 19, 464–469.

IUCN, 2008. IUCN Red List of Threatened Species. <www.iucnredlist.org>.

JNCC, 2008. The Wildlife and Countryside Act 1981. British Government, Joint National Conservation Committee, United Kingdom.

Johnson, J.A., Watson, R.T., Minde, D.P., 2005. Prioritizing species conservation: does the Cape Verde kite exist? Proc. Roy. Soc. B 272, 1365–1371.

Karl, S., Bowen, B., 1999. Evolutionary significant units versus geopolitical taxonomy: molecular systematics of an endangered sea turtle (genus *Chelonia*). Conserv. Biol. 13, 990–999.

Kennedy, K., 1999. Endangered and Threatened Wildlife and Plants; Final Rule to Remove the Plant *Echinocereus lloydii* (Lloyd's hedgehog cactus) from the federal list of endangered and threatened plants. Department of the Interior, United States Fish and Wildlife Services, Federal Register, Rules and Regulations, Washington, DC. pp. 33796–33800.

Khuroo, A.A., Dar, G.H., Khan, Z.S., Malik, A.H., 2007. Exploring an inherent interface between taxonomy and biodiversity: current problems and future challenges. J. Nat. Conserv. 15, 256–261.

Knapp, S., Lughadha, E.N., Paton, A., 2005. Taxonomic inflation, species concepts and global species lists. Trends Ecol. Evol. 20, 7–8.

Leme, E.M.C., 2003. Nominal extinction and the taxonomist's responsibility: the example of Bromeliaceae in Brazil. Taxon 52, 299–302.

Lozano, F.D., Saiz, J.C.M., Ollero, H.S., Schwartz, M.W., 2007. Effects of dynamic taxonomy on rare species and conservation listing: insights from the Iberian vascular flora. Biodiv. Conserv. 16, 4039–4050.

Mace, G.M., 2004. The role of taxonomy in species conservation. Philos. Trans. Roy. Soc. B 359, 711–719.

May, R.M., 1990. Taxonomy as destiny. Nature 347, 129–130.

McNeely, J.A., 2002. The role of taxonomy in conserving biodiversity. J. Nat. Conserv. 10, 145–153.

Meiri, S., Mace, G.M., 2007. New taxonomy and the origin of species. PLoS Biology 5, 1385–1386.

Meyer, N., Meierott, L., Schuwerk, H., Angerer, O., 2005. Beiträge zur Gattung *Sorbus* in Bayern. Sonderband der Berichte der Bayerischen Botanischen Gesellschaft, Munich, Germany, 216 pp.

Miller, J.M., Chambers, K.L., 2006. Systematics of *Claytonia* (Portulacaceae). Syst. Bot. Monogr. 78, 1–236.

Missouri Natural Heritage Program, 2009. Missouri Species and Communities of Conservation Concern Checklist. Missouri Department of Conservation, Jefferson City, Missouri, USA, p. 54.

Murray, D.L., Waits, L.P., 2007. Taxonomic status and conservation strategy of the endangered red wolf: a response to Kyle et al. (2006). Conserv. Genet. 8, 1483–1485.

National Research Council, 1996. Upstream: Salmon and Society in the Pacific Northwest. National Academy Press, Washington, DC.

Nielson, M., Lohman, K., Sullivan, J., 2001. Phylogeography of the tailed frog (*Ascaphus truei*): implications for the biogeography of the Pacific Northwest. Evolution 55, 147–160.

NMFS, USFWS, 2007. Green Sea Turtle (*Chelonia mydas*): 5-Year Review. National Marine Fisheries Service and The US Fish and Wildlife Service, Silver Spring, Maryland, USA.

Nowak, R.M., 2002. The original status of wolves in eastern North America. Southeast. Natural. 1, 95–130.

Nowak, R.M., 2003. Wolf evolution and taxonomy. In: Mech, L.D., Boitani, L. (Eds.), Wolves: Behavior, Ecology and Conservation. University of Chicago Press, Chicago, Illinois, pp. 239–258.

Padial, J.M., De La Riva, I., 2006. Taxonomic inflation and the stability of species lists: the perils of Ostrich's behavior. Syst. Biol. 55, 859–867.

Patten, M.A., Pruett, C.L., 2009. The song sparrow, *Melospiza melodia*, as a ring species: patterns of geographic variation, a revision of subspecies, and implications for speciation. Syst. Biodiv. 7, 33–62.

Platz, J.E., Mecham, J.S., 1979. *Rana chiricahuensis*, a new species of leopard frog (*Rana pipiens* complex) from Arizona. Copeia 383, 390.

Poole, J.M., Riskind, D.H., 1987. Endangered, Threatened, or Protected Native Plants of Texas. Texas Parks and Wildlife Department, Austin, Texas.

Powell, A.M., Zimmerman, A.D., Hilsenbeck, R.A., 1991. Experimental documentation of natural hybridization in Cactaceae – origin of Lloyds Hedgehog cactus, *Echinocereus* x *lloydii*. Plant Syst. Evol. 178, 107–122.

Rising, J.D., 2005. Ecological and genetic diversity in the seaside sparrow. Birding 37, 490–496.

Rorabaugh, J., 2002. Endangered and Threatened Wildlife and Plants; Listing of the Chiricahua Leopard Frog (*Rana chiricahuensis*). United States Fish and Wildlife Service, Federal Register, Washington, DC. pp. 40789–40811.

Russello, M.A., Glaberman, S., Gibbs, J.P., Marquez, C., Powell, J.R., Caccone, A., 2005. A cryptic taxon of Galapagos tortoise in conservation peril. Biol. Lett. 1, 287–290.

Scheuerer, M., Ahlmer, W., 2003. Rote Liste gefährdeter Gefäβpflanzen Bayerns mit regionalisierter Florenliste. Bayerische Landesamt für Umweltschutz, Munich, Germany. p. 372.

Schliebe, S., Johnson, K., 2008. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Polar Bear (*Ursus maritimus*) throughout its Range. United States Fish and Wildlife Service, Federal Register, Washington, DC. pp. 28212–28303.

Talbot, S.L., Shields, G.F., 1996a. Phylogeography of brown bears (*Ursus arctos*) of Alaska and paraphyly within the Ursidae. Mol. Phylogenet. Evol. 5, 477–494.

Talbot, S.L., Shields, G.F., 1996b. A phylogeny of the bears (Ursidae) inferred from complete sequences of three mitochondrial genes. Mol. Phylogenet. Evol. 5, 567–575.

USFWS, 1995. Snake River Aquatic Species Recovery Plan. Department of the Interior, United States Fish and Wildlife Service, Boise, Idaho, USA, pp. 1–92.

USFWS, 2007a. Endangered and Threatened Wildlife and Plants; Final Rule to Remove the Idaho Spring Snail (*Pyrgulopsis* (=*Fontelicella*) *idahoensis*) from the List of Endangered and Threatened Wildlife. Department of the Interior, United States Fish and Wildlife Service, Federal Registry, Rules and Regulations, Washington, DC, pp. 43560–43563.

USFWS, 2007b. Red Wolf (*Canis rufus*) 5-Year Review: Summary and Evaluation. Department of the Interior, United State Fish and Wildlife Service, Manteo, North Carolina, USA, pp. 1–58.

USFWS, 2007c. News Release: Service Removes Idaho Spring Snail from the Endangered Species List. Department of the Interior, United States Fish and Wildlife Service, Boise, Idaho, USA.

USFWS, 2008. Press Release: Polar Bear. Department of the Interior, United States Fish and Wildlife Service, Arlington, Virgina, USA.

Utevsky, S.Y., Trontelj, P., 2005. A new species of the medicinal leech (Oligochaeta, Hirudinida, *Hirudo*) from Transcaucasia and an identification key for the genus Hirudo. Parasitol. Res. 98, 61–66.

Waits, L.P., Sullivan, J., O'Brien, S.J., Ward, R.H., 1999. Rapid radiation events in the family Ursidae indicated by likelihood phylogenetic estimation from multiple fragments of mtDNA. Mol. Phylogenet. Evol. 13, 82–92.

Walters, M.J., 1992. A Shadow and A Song. Chelsea Green Publishing Co., Post Mills, VT, USA.

Wayne, R.K., Jenks, S.M., 1991. Mitochondrial DNA analysis implying extensive hybridization of the endangered Red Wolf *Canis rufus*. Nature 351, 565–568.

Williams, J., 2009. Interior Secretary Salazar finally restores ESA law, but polar bear loses out. The Examiner, April 29, 2009, Politics Section. <http://www.examiner.com/x-5266-Seattle-Environmental-Policy-Examiner-y2009m4d29-Interior-Secretary-Salazar-finally-restores-ESA-law-but-polar-bears-lose-out> (accessed 28.06.09).

Wilson, D.E., Reeder, D.M., 2005. Mammal Species of the World: A Taxonomic and Geographic Reference, 3rd ed. Johns Hopkins University Press, Baltimore.

Wolf, J., Tautz, D., Trillmich, F., 2007. Galapagos and Californian sea lions are separate species: genetic analyses of the genus *Zalophus* and its implications for conservation management. BMC: Front. Zool. 4, 20.

Zink, R.M., Barrowclough, G.F., Atwood, J.L., Blackwell-Rago, R.C., 2000. Genetics, taxonomy, and conservation of the threatened California Gnatcatcher. Conserv. Biol. 14, 1394–1405.