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Contributed Paper

Not Knowing, Not Recording, Not Listing: Numerous Unnoticed Mollusk Extinctions

CLAIRE RÉGNIER,*‡ BENOÎT FONTAINE,† AND PHILIPPE BOUCHET*

*Muséum National d'Histoire naturelle, Département Systématique et Evolution—Malacologie—USM 602, Case postale 51, 55 rue Buffon, 75231 Paris, Cedex 05, France

†Muséum National d'Histoire naturelle, UMR 5173—Conservation des Espèces, Suivi et Restauration des Populations Département Ecologie et Gestion de la Biodiversité Muséum National d'Histoire Naturelle CP 51, 55 rue Buffon, 75005 Paris, France

Abstract: *Mollusks are the group most affected by extinction according to the 2007 International Union for Conservation of Nature (IUCN) Red List, despite the group having not been evaluated since 2000 and the quality of information for invertebrates being far lower than for vertebrates. Altogether 302 species and 11 subspecies are listed as extinct on the IUCN Red List. We reevaluated mollusk species listed as extinct through bibliographic research and consultation with experts. We found that the number of known mollusk extinctions is almost double that of the IUCN Red List. Marine habitats seem to have experienced few extinctions, which suggests that marine species may be less extinction prone than terrestrial and freshwater species. Some geographic and ecologic biases appeared. For instance, the majority of extinctions in freshwater occurred in the United States. More than 70% of known mollusk extinctions took place on oceanic islands, and a one-third of these extinctions may have been caused precipitously by introduction of the predatory snail* Euglandina rosea*. We suggest that assessment of the conservation status of invertebrate species is neglected in the IUCN Red List and not managed in the same way as for vertebrate species.*

Keywords: conservation status, extinction, geographic bias, islands, IUCN Red List, mollusk, taxonomic bias

No Conocer, No Registrar, No Enlistar: Numerosas Extinciones de Moluscos No Detectadas

Resumen: *De acuerdo con la Lista Roja IUCN (Unión Internacional para la Conservación de la Naturaleza) 2007 los moluscos son el grupo más afectado por la extinción, no obstante que el grupo no ha sido evaluado desde 2000 y que la calidad de la información para invertebrados es mucho menor que para vertebrados. En total, la Lista Roja IUCN incluye 302 especies y 11 subespecies consideradas extintas. Reevaluamos las especies de moluscos enlistadas como extintas mediante una investigación bibliográfica y la consulta con expertos. Encontramos el que números de extinciones de moluscos conocidas es casi el doble del que señala la Lista Roja IUCN. Los hábitats marinos parecen haber experimentado pocas extinciones, lo que sugiere que las especies marinas pueden ser menos propensas a la extinción que las especies terrestres y dulceacuícolas. Aparecieron algunos sesgos geográficos y ecológicos. Por ejemplo, la mayoría de las extinciones en agua dulce ocurrieron en los Estados Unidos, Mpas de 70% de las extinciones de moluscos conocidas se llevaron a cabo en islas oceánicas, y un tercio de esas extinciones pueden haber sido precipitadas por la introducción del caracol depredador* Euglandina rosea*. Sugerimos que la evaluación del estatus de conservación de especies invertebradas está descuidada en la Lista Roja IUCN y no es manejada de la misma manera que vertebrados.*

Palabras Clave: estatus de conservación, extinción, islas, Lista Roja IUCN, molusco, sesgo geográfico, sesgo taxonómico

‡*email cregnier@mnhn.fr*

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Introduction

Conservation strategies require knowledge about extinction-prone groups and good estimates of extinction risk. The International Union for Conservation of Nature (IUCN) Red List has become an essential source of information for conservation action and is widely recognized as the most comprehensive compilation of extinct and threatened species (Mace & Lande 1991; Rodrigues et al. 2006). Yet IUCN figures do not reflect the current trend of great losses of biodiversity (Mace 1995; Lamoreux et al. 2003). The IUCN Red List (IUCN 2007) shows that 850 species have become extinct since 1500, which is fewer than two species per year and is the same order of magnitude of extinctions as background extinction rates estimated from the fossil record (May et al. 1995). Moreover, there is a huge taxonomic bias in the assessment of species' conservation status. According to Baillie et al. (2004), the conservation status of almost 90% of mammal species and of all bird and amphibian species has been evaluated, whereas only 3% of mollusk species and 0.08% of insect species have been assessed. Indeed, invertebrates receive much less attention than vertebrates, and our knowledge of them is sparse (Gaston & May 1992; McKinney 1999).

With 302 species and 11 subspecies listed as extinct, mollusks are the group paying the most severe documented tribute to the crisis according to IUCN figures (302 vs. 271 for all terrestrial vertebrates). In this context mollusks represent an interesting group through which to address several questions regarding the representativeness of the IUCN Red List. What proportion of species that are known to be extinct by specialists is captured by the IUCN Red List? Where are the main gaps in terms of geographical distribution and biomes? Extinct mollusks on the IUCN Red List have not been evaluated and assessed since 1996, except for 82 North American species evaluated in 2000. Is this lack of assessment due to the fact that there have been no other mollusk extinctions since then, or are mollusks simply not listed? If the latter, why are they not listed?

Methods

Throughout this paper, we focus on extinct species only and do not deal with species listed as threatened. We reviewed all mollusk species listed as extinct on the IUCN Red List by contacting the assessors of each species and asking them to provide the source of information that led to the listing or to a downgrading to threatened status if appropriate. As far as possible, we obtained a published reference supporting the status for each species. If no reference was available, we noted the justification as personal communication. We provisionally considered species listed as extinct for which we could find no published reference to support this status.

We scanned selected references for unlisted cases of extinct species. These were taxonomic papers (Abdou & Bouchet 2000; Griffiths & Florens 2004), conservation papers (Whitten et al. 1987; Fontaine et al. 2007), and regional checklists of species. This resulted in an expanded list with additions of extinct (EX) or possibly extinct (PoEX) species. We listed as PoEX species that may have gone extinct but for which no recent field surveys had confirmed this, and species cited as extinct in the literature without any details provided to support this assertion. This category is not recognized by the IUCN; rather, these species are listed as critically endangered with a flag of possibly extinct or as data deficient (IUCN 2001), depending on the case. We also listed as PoEX species whose systematic validity was not clearly established, such as possible synonyms or subspecies.

For all listed species (those on the IUCN Red List and those newly assessed as extinct), we asked experts (listed in the Acknowledgments) to

- confirm or contradict the validity of the species listed, supported by literature references or as personal communication. (Of special interest were cases in which a taxon was treated by some authors as a valid species and by others as a valid subspecies or synonym. Our goal was to distinguish taxonomic extinction from true extinction.);
- confirm or contradict the conservation status of the species on our list, again supported by literature references or supported by as personal communication; and
- identify species omitted from the expanded list.

Results

Altogether 302 mollusk species and 11 subspecies were originally listed as extinct on the 2007 IUCN Red List. Of these, experts recognized 33 species and two subspecies as still extant. Twenty-seven of these species had been recently rediscovered in the field, and eight had to be considered as taxonomic extinctions (synonyms of other species that still survive). Only 269 species and nine subspecies were correctly listed as extinct on the IUCN Red List. Information from the literature and the experts provided 263 new cases of extinct species and 25 of extinct subspecies; 17 others had initially been included as extinct, based on the literature but were removed following expert consultation. The full list of extinct mollusk species and subspecies is available on request from C.R. New cases of mollusk extinctions should be taken into account in future releases of the IUCN Red List (M.B. Seddon, personal communication).

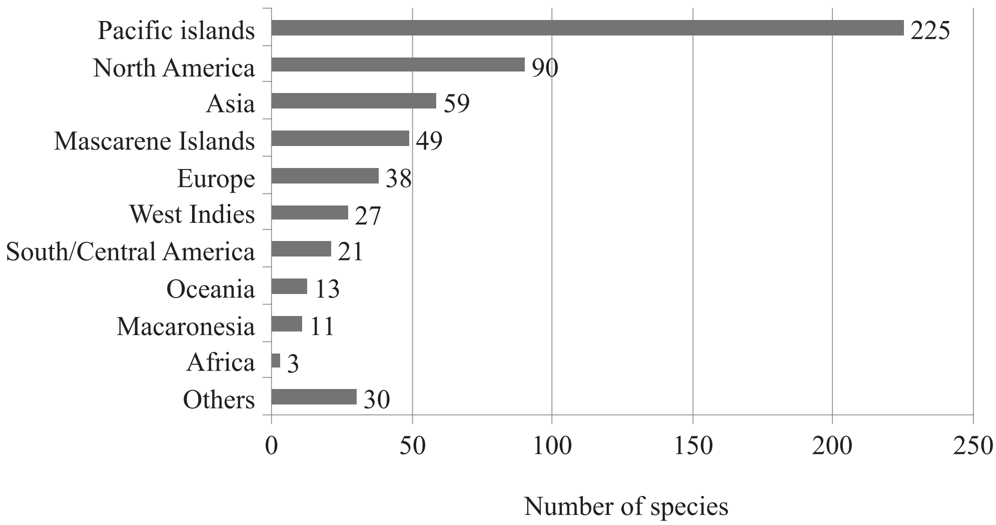

Figure 1. Geographical distribution of extinct mollusks: Pacific islands (Hawaii, French Polynesia, American Samoa, Clipperton, Cook Islands, Fiji, Guam, New Caledonia, Mariana Islands, Pitcairn Islands), North America (United States, Canada), Asia (China, India, Indonesia, Japan, Malaysia, Pakistan, Philippines, Vietnam), Mascarene Islands (Mauritius, Reunion, Rodrigues), Europe (Austria, Croatia, France, Greece, Montenegro, Portugal, Serbia), West Indies (Antilles, Cuba, Guadeloupe, Haiti, Jamaica, Martinique, Trinidad), South/Central America (Argentina, Brazil, Columbia, Ecuador, Mexico, Paraguay, Venezuela), Oceania (Australia, Norfolk Islands), Macaronesia (Canary Islands, Madeira), Africa (South Africa, Mayotte), others (Bermuda, Israel, Saint Helena, Seychelles).

Known extinctions of mollusks were unevenly distributed among geographical areas. The two most important groups in terms of extinction figures were North American and Pacific Island species (Fig. 1). All North American, European, Japanese, and Australian mollusk extinctions were documented by researchers native to each of these countries. Among the 334 extinct species native to countries other than the United States, Europe, Japan, and Australia, 26% were recorded by North American researchers, 54% by Europeans, and 15% by Australians. We documented few extinctions among marine mollusk species (Fig. 2): only four cases of 566 despite a wide search by a large number of people (shell collectors). If extinctions had occurred, some would have been noticed.

Among the 140 freshwater extinctions we documented, 83 occurred in the United States (Fig. 3), including 50 in the Alabama River system (Alabama, Cahaba, Coosa, and Mobile rivers). Balkan species represented another important group of extinct freshwater mollusks. We recorded 29 extinctions in this region (Fig. 3). For freshwater too, geographical biases were important. Apart from the two main groups of extinctions (United States and Balkans), freshwater extinctions were recorded in small numbers in only a few areas (Fig. 3). This imbalance may be due to a sampling or study artifact. Of 27 known areas of special importance for freshwater mollusk diversity (Strong et al. 2008), 17 lacked data on species conservation status, including African great lakes, Madagascar, and lakes and river basins in Southeast Asia.

Another important component of freshwater molluskan biodiversity that remains mostly unknown and for which very few data were available in terms of species conservation status is the spring and groundwater snails. Among the 566 extinct mollusk species, 400 are from oceanic islands, representing 71% of all listed mollusk extinctions. And among these 400 extinct mollusk species,

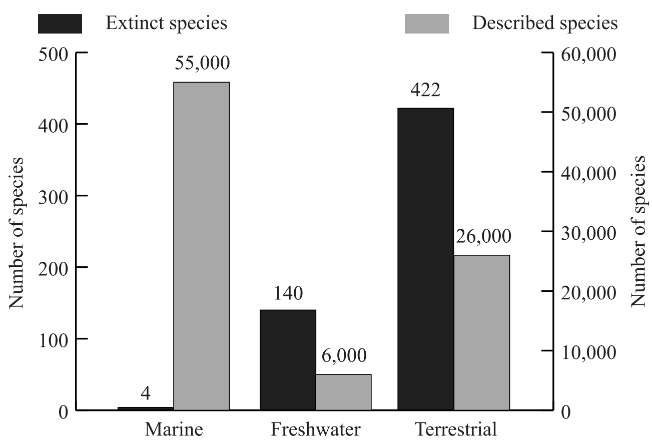

Figure 2. Number of extinct mollusk species (left) compared with the number of described species in marine, freshwater, and terrestrial biotas (right) (after Bouchet & Lydeard et al. 2004).

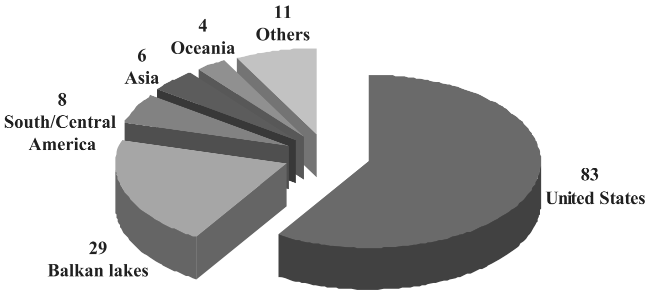

Figure 3. Geographical origin and number of extinct freshwater mollusks.

327 are endemic to the most isolated islands of the world (UNEP 1998), as ranked by an index of isolation based on distances to the nearest island, island group, and continent. The listed extinct island species are mostly from Hawaii, French Polynesia, and the Mascarene Islands (Fig. 1), where research is very active, and this introduces a geographical bias within the listing of extinct island species. Of the 400 extinct species we listed from oceanic islands, 234 lived on islands to which *Euglandina rosea* had been introduced, and it is highly probable that of these 234 extinctions, 134 of them were ultimately caused by the introduction of *E. rosea*.

Discussion

Uneven and Biased Nature of Mollusk Extinctions

The biased distribution of mollusk extinctions we found has been noted previously. For these poorly known species (i.e., invertebrate species), knowledge of their conservation status comes from taxonomists, and 80% of taxonomists are based in North America or Europe and few (only 4%) are Latin American or African. However, biodiversity is richest in countries with fewer taxonomists (Gaston & May 1992). These figures match well with our observations. The sparse knowledge available for biodiversity-rich countries is partly due to a lack of local workers. This is not the situation in Europe, where there are a lot of taxonomists to notice changes in population trends of mollusks and numerous cases of documented mollusk extinctions are a direct consequence of a large number of workers in this field. But molluskan faunas from Pacific islands and North America have another characteristic that makes their extinction figures stand out. These two faunas (especially freshwater fauna for North America [Bogan et al. 1995]) have a lot of very restricted endemics that are much and easily affected by environmental changes induced by human settlement.

Marine Mollusk Extinctions

Despite the fact that marine mollusks are more diverse than nonmarine species (Bouchet 2006), only one supplementary case of extinction was found. This trend was not inherent to the molluskan fauna: only 16 extinct marine species, from mammals to algae, are listed in the 2007 IUCN Red List. This may be because in published studies on conservation biology marine habitats are underrepresented (Carlton 1993; Chapman 1999; Reaka-Kudla 1997). This trend may be changing because marine habitats are becoming a topic of concern (Powles et al. 2000; Dulvy et al. 2003; Hilborn 2007). In papers on this issue, there is conflation of "biological extinction" (our focus here) and "commercial extinction" (Dulvy et al. 2004; Worm et al. 2006; Hilborn 2007), probably because of confusion between biodiversity loss (global extinctions) and declining stocks of commercially valuable species (Briggs 2007). The lack of quantitative data on marine invertebrate abundances, ranges, habitat requirements, dispersal, and connectedness among populations prevented us from concluding anything about their conservation status (Chapman 1999). This does not mean marine invertebrates are extinction proof. In vulnerable marine habitats, such as coral reefs, where species are part of coevolved associations, worldwide episodes of coral bleaching probably have serious consequences for species that are interdependant and may have led to several unnnoticed extinctions (Reaka-Kudla 1997). But no such cases of extinctions have yet been recorded.

It is commonly thought that marine organisms are resistant to human-caused extinction because most of them have larvae with a long planktonic drifting stage and large geographic ranges (Carlton 1993; Culotta 1994; McKinney 1998). The very few extinctions listed for marine organisms and the only additional case of a marine mollusk extinction we documented confirmed this is likely to be the case. Our general conclusion concerning marine extinctions is that marine mollusks (and marine species in general) are likely to be less extinction prone than nonmarine species.

Freshwater Mollusk Extinctions

Flowing waters are probably the most endangered ecosystem on Earth, and this is because of human activities (Allan & Flecker 1993; Malmqvist & Rundle 2002). That mollusks are endangered in river system in the United States is well known. We illustrated this for the Alabama River system, which is highly polluted because of infrastructure development (Bogan 2006). The effect of habitat degradation is affecting mollusks all the more because the freshwater molluskan fauna of North America has a lot of very restricted endemics.

The Balkan region is rich in freshwater fauna (Griffith et al. 2004; Gloër et al. 2007). Many gastropod species in this region have small ranges and are restricted to small hydrographic systems: rivers, lakes, and springs (Fig. 4). The high level of endemism in the Balkan freshwater molluskan fauna is due to the karstic landscape, which is

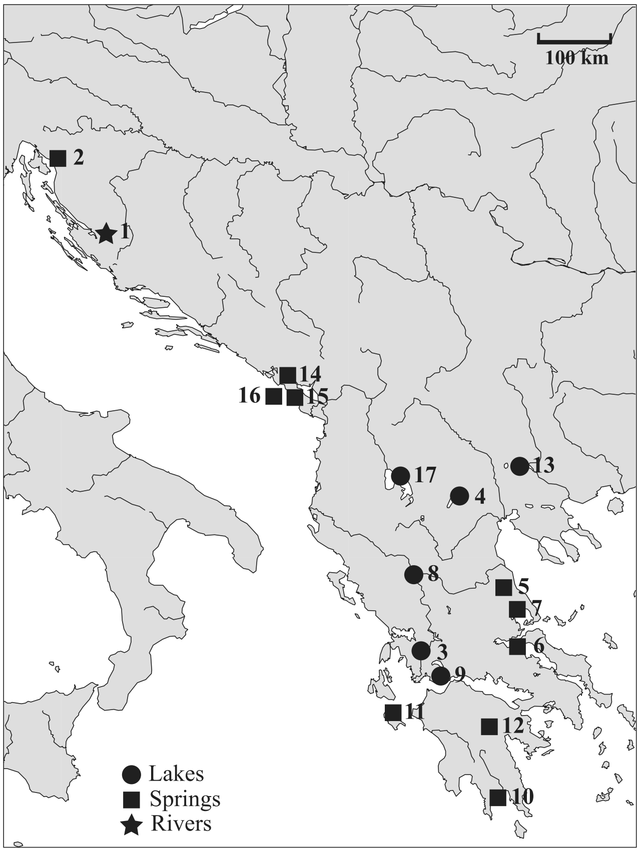

Figure 4. Locations of the extinct mollusks of the Balkan region: 1, Belgrandiella zermanica, Dalmatinella fluviatilis, Islamia zermanica, Tanousia zrmanjae*; 2,* Graziana lacheineri adriolitoralis, Vinodolia fiumana*; 3,* Dianella schlickumi*; 4,* Graecoanatolica vegorriticola*; 5,* Graecorientalia vrissiana*; 6,* Grossuana serbica vurliana*; 7,* Heleobia achaja sorella, Turcorientalia hohenackeri hohenackeri*; 8,* H. steindachneri, I. epirana, Orientalina curta albanica, Paladilhiopsis janinensis*; 9,* I. graeca, Pseudoislamia balcanica, Trichonia trichonica, Valvata klemmi*; 10,* I. hadei*; 11,* Pseudamnicola macrostoma*; 12,* T. kephalovrissonia*; 13,* G. macedonica*; 14,* Antibaria notata, V. gluhodolica*; 15,* Bracenica spiridoni*; 16,* V. matjasici*; 17,* Ohridohauffenia drimica.

characterized by a spring and river hydrography in which small systems are completely isolated from one another (Radoman 1985). Narrow ranges and isolation have made these species more vulnerable to habitat degradation and in many cases have resulted in extinction.

Data on the status of groundwater species are rare. For example, the impact of pollutants and chemical fertilizers on hypogean faunas remains unknown, although researchers are beginning to address this issue (Canivet et al. 2001). Conservation studies of subterranean faunas have been done only in the Balkans (Szarowska & Albrecht 2004; Szarowska 2006) and in the Great Artesian Basin of Australia (Ponder 2003). These studies showed that drawdown resulting from water extraction leads to endangerment or extinction of many species. No doubt the difficulty of reaching these species habitats accounts for the lack of assessment.

Oceanic Islands

Many more mollusk extinctions have occurred on oceanic islands than on continents. This imbalance may be explained by the intrinsic vulnerability of oceanic island species (island endemics have small ranges and small populations) and their evolution in isolation from predators and competitors, which makes them extremely prone to extinction (Pimm 1991; Purvis et al. 2000). In addition, it is inherently difficult to record extinctions, but it is much easier on islands because species have small ranges and small populations. On very small islands (such as Gambier or Austral islands in French Polynesia), when an endemic species is not found despite considerable survey efforts, very little doubt remains about its survival (Abdou & Bouchet 2000).

Extinctions on oceanic islands have been caused mostly by habitat degradation and introduced species. Cowie (1997) documented 59 terrestrial and 22 freshwater snail and slug species that have been recorded as aliens in the Hawaiian Islands alone. The case of *E. rosea* deserves special attention. *E. rosea* is a predatory snail that was introduced to several Pacific islands to control the giant African snail (*Achatina fulica*). It has had a dramatic impact on populations of native land snail. Two cases of massive extinctions in endemic molluskan faunas caused by *E. rosea* have been well documented. In the Society Islands, *E. rosea* eradicated 51 endemic species of Partulidae in <10 years (Coote & Loève 2003), and in Hawaii 56 terrestrial species of Amastridae and Achatinellidae that we list may also have became extinct as a result of predation by the carnivorous snail (Hadfield 1986; Cowie 1992, 2001*a*; Hadfield et al. 1993). *E. rosea* was the precipitous cause of these extinctions (Griffiths et al. 1993; Civeyrel & Simberloff 1996; Cowie 2001*b*), but populations of these endemic snails were already weakened by decades of habitat destruction, overcollecting, and predation by other accidentally introduced species (Hadfield 1986; Cowie 1992). The other extinct species native to islands where *E. rosea* was present were extinct in most cases before introduction of the carnivorous snail.

The current, most serious threat to native island mollusks is probably the introduced flatworm *Platydemus manokwari*. The flatworm, native to New Guinea, has been introduced in attempts to control *A. fulica*. At present, it is affecting endemic land snails on Guam and Rota (Robinson & Hollingsworth 2005), in Samoa (Cowie & Robinson 2003), and in the Ogasawara Islands (Okochi et al. 2004). These introduced predators may

Figure 5. Summary of the updated mollusk species and subspecies extinctions.

rapidly cause the extinction of many more land snails native to oceanic islands.

Unlisted but Not Unnoticed

Assessing rates of extinction for invertebrate taxa is obstructed by differences in the quality of information about each group (McKinney 1999) and by uneven numbers of vertebrate experts and invertebrate experts (Gaston & May 1992). Moreover, the difficulty of ruling on the conservation status of species is amplified for invertebrate taxonomists because not only are there fewer of them in relation to terrestrial vertebrate experts but also the number of species to deal with is colossal (as high as 99% of animals; Ponder & Lunney 1999). Plus, most invertebrate species are small. For these two reasons reaching a decision concerning their conservation status involves extensive and detailed survey work that can take in some cases a lifetime of work. Vertebrate experts, in contrast, tend to focus on one or a few favorite species and to go out on targeted field-survey expeditions. Despite these difficulties, some scattered results of thorough survey works reach the stage of publication, and our <3 months of bibliographic research and consultation with experts led to a doubling of the number of listed extinct mollusk species. Why, when monitoring of the conservation status of mammals and birds is so accurate, were these extinctions not captured by the IUCN until now? The extinctions we recorded had been known and published for more than 10 years in many cases. For mollusks (and all invertebrates) there is a disconnect between extinctions known to experts or published in the scientific literature and extinctions on the IUCN Red List, whereas for birds and mammals, the IUCN Red List is the scientific reference. The list is designed for vertebrates and relies on an important task force of ecological researchers and conservation biologists who are monitoring, observing the state of biodiversity, and relaying their data to the IUCN almost in real time. For invertebrates, taxonomists—not ecological researchers—hold the knowledge of species population trends. This knowledge is published but does not reach the IUCN. Thus, there is an additional stage in listing an invertebrate extinction in the "IUCN way." For mammals and birds, the process is (1) knowing and (2) listing, whereas for invertebrates it seems to be (1) knowing and (2) sometimes recording, or (1) knowing, (2) recording, and (3) not listing and often not knowing. This difference in the way of documenting extinctions between invertebrates and terrestrial vertebrates may partly explain the imbalance in the number of listed extinctions per major taxonomic group.

Conclusion

At the onset of our study, out of 850 known extinct species globally, 302 were mollusks, 278 of which were correctly listed as extinct. Today, the number of mollusk extinctions has almost doubled (Fig. 5) and is higher than the number of extinctions in all other taxa combined. Do mollusks really account for half the toll? They certainly account for half the toll of documented extinctions but certainly not for half the toll of what is really extinct (i.e., both documented and overlooked extinctions). Invertebrate species receive much less publicity and attract disproportionately minor research effort relative to vertebrates (Lydeard et al. 2004). Indeed, there is a mismatch between the number of scientists working on birds and mammals and the very few taxonomists specializing in invertebrate taxa. If one adds to this the unbalanced repartition of human effort and funding in relation to the richest biodiversity locations, it becomes clear that these two phenomena are influencing this uneven number of documented extinctions.

Yet, the difficulties encountered in recording mollusk extinctions are less critical than those faced in recording extinctions in other invertebrate taxa, such as insects. Recording mollusk extinctions in the field is facilitated by the fact that one can still find dead shells from species that became extinct during the 19th century (Bouchet & Abdou 2003; Griffiths & Florens 2006). Compared with mollusks, the number of documented insect extinctions is amazingly small: 60 according to the 2007 IUCN Red List (IUCN 2007) of about 950,000 described species. Baillie et al. (2004) estimated that the conservation status of 771 insect species had been evaluated and that 73% of them are listed as threatened by the IUCN. This provides a good idea of the huge number of extinctions being missed and makes it clear how much the present listing of extinctions is biased. If "[m]ost extinctions estimated to have occurred in the historical past, or predicted to occur in the future, are of insects" (Dunn 2005), then no doubt a huge number of insect extinctions have gone unnoticed since 1500. The same work we did for mollusks could be applied to insects and would surely increase dramatically the number of documented extinctions on the IUCN Red List.

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Supporting Information

An updated list of mollusk extinctions (Appendix S1) and sources for updating the extinct species list (Appendix S2) are available as part of the on-line article. The authors are responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Literature Cited

Abdou, A., and P. Bouchet. 2000. Nouveaux gastéropodes Endodontidae et Punctidae (Mollusca, Pulmonata) récemment éteints de l'archipel des Gambiers (Polynésie). Zoosystema **22:**689–707.

Allan, J. D., and A. S. Flecker. 1993. Biodiversity conservation in running waters. BioScience **43:**32–43.

Baillie, J. E. M., et al. 2004. IUCN Red List of threatened species—a global species assessment. International Union for Conservation of Nature, Gland, Switzerland, and Cambridge, United Kingdom.

Bogan, A. E. 2006. Conservation and extinction of the freshwater molluscan fauna of North America. Page 445 in C. F. Sturm, T. A. Pearce, and A. Valdes, editors. The mollusks: a guide to their study, collection and preservation. American Malacological Society, Philadelphia, Pennsylvania.

Bogan, A. E., J. M. Pierson, and P. Hartfield. 1995. Decline in the freshwater gastropod fauna in the Mobile Bay basin. Pages 249–252 in E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac, editors. Our living resources: a report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. U.S. Department of the Interior, National Biological Service, Washington, D.C.

Bouchet, P. 2006. The magnitude of marine biodiversity. Pages 31–64 in C. M. Duarte, ed. The exploration of marine biodiversity—scientific and technological challenges. Fondacion BBVA, Bilbao, Spain.

Bouchet, P., and A. Abdou. 2003. Endemic land snails from the Pacific Islands and the museum record: documenting and dating the extinction of the terrestrial Assimineidae of the Gambier Islands. Journal of Molluscan Studies **69:**165–170.

Briggs, J. C. 2007. Biodiversity loss in the ocean: how bad is it? [author reply]. Science **316:**1281–1284.

Canivet, V., P. Chambon, and J. Gibert. 2001. Toxicity and bioaccumulation of arsenic and chromium in epigean and hypogean freshwater macroinvertebrates. Archives of Environmental Contamination and Toxicology **40:**345–354.

Carlton, J. T. 1993. Neoextinctions of marine invertebrates. American Zoologist **33:**499–509.

Chapman, M. G. 1999. Are there adequate data to assess how well theories of rarity apply to marine invertebrates? Biodiversity and Conservation **8:**1295–1318.

Civeyrel, L., and D. Simberloff. 1996. A tale of two snails: is the cure worse than the disease? Biodiversity and Conservation **5:**1231–1252.

Coote, T., and E. Loève. 2003. From 61 species to five: endemic tree snails of the Society Islands fall prey to an ill-judged biological control programme. Oryx **37:**91–96.

Cowie, R. H. 1992. Evolution and extinction of Partulidae, Endemic Pacific island land snails. Philosophical Transactions of the Royal Society of London—Biological Sciences **335:**167–191.

Cowie, R. H. 1997. Catalog and bibliography of the nonindigenous nonmarine snails and slugs of the Hawaiian Islands. Bishop Museum Occasional Papers **50:**1–66.

Cowie, R. H. 2001*a*. Can snails ever be effective and safe biocontrol agents? International Journal of Pest Management **47:**23–40.

Cowie, R. H. 2001*b*. Invertebrate invasions on Pacific Islands and the replacement of unique native faunas: a synthesis of the land and freshwater snails. Biological Invasions **3:**119–136.

Cowie, R. H., and A. C. Robinson. 2003. The decline of native Pacific island faunas: changes in status of the land snails of Samoa through the 20th century. Biological Conservation **110:**55–65.

Culotta, E. 1994. Is marine biodiversity at risk? Science **263:**918–920.

Dulvy, N. K., Y. Sadovy, and J. D. Reynolds. 2003. Extinction vulnerability in marine populations. Fish and Fisheries **4:**25–64.

Dulvy, N. K., J. R. Ellis, N. B. Goodwin, G. Alastait, J. D. Reynolds, and S. Jennings. 2004. Methods of assessing extinction risk in marine fishes. Fish and Fisheries **5:**255–276.

Dunn, R. R. 2005. Modern insect extinctions, the neglected majority. Conservation Biology **19:**1030–1036.

Fontaine, B., et al. 2007. The European union's 2010 target: putting rare species in focus. Biological Conservation **139:**167–185.

Gaston, K. J., and R. M. May. 1992. The taxonomy of taxonomists. Nature **356:**281–282.

Gloër, P., C. Albrecht, and T. Wilke. 2007. Enigmatic distribution patterns of the Bithyniidae in the Balkan Region (Gastropoda: Rissooidea). Mollusca **25:**13–22.

Griffith, H. I., B. Kryštufek, and J. M. Reed. 2004. Balkan biodiversity: pattern and process in the European hotspot. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Griffiths, O. L., and F. B. Florens. 2004. Ten new species of Mascarene land snails (Mollusca: Gastropoda) and their conservation status. Molluscan Research **24:**161–177.

Griffiths, O. L., and V. F. B. Florens. 2006. Nonmarine molluscs of the Mascarene Islands (Mauritius, Rodrigues and Réunion) and the northern dependencies of Mauritius. Bioculture Press, Mauritius.

Griffiths, O. L., A. Cook, and S. M. Wells. 1993. The diet of the introduced carnivorous snail *Euglandina rosea* in Mauritius and its implications for threatened island gastropod faunas. Journal of Zoology **229:**79–89.

Hadfield, M. G. 1986. Extinction in Hawaiian achatinelline snails. Malacologia **27:**67–81.

Hadfield, M. G., S. E. Miller, and A. H. Carwile. 1993. The decimation of endemic Hawaiian tree snails by alien predators. American Zoologist **33:**610–622.

Hilborn, R. W. 2007. Biodiversity loss in the ocean: how bad is it? [author reply]. Science **316:**1281–1284.

IUCN (International Union for Conservation of Nature). 2001. IUCN Red List categories and criteria. Version 3.1. IUCN, Gland, Switzerland.

IUCN (International Union for Conservation of Nature). 2007. 2007 IUCN Red List of threatened species. IUCN, Gland, Switzerland.

Lamoreux, J., et al. 2003. Value of the IUCN Red List. Trends in Ecology & Evolution **18:**214–215.

Lydeard, C., et al. 2004. The global decline of nonmarine mollusks. BioScience **54:**321–330.

Mace, G. M. 1995. Classification of the threatened species and its role in conservation planning. Pages 197–213 in J. H. Lawton and R. M. May, editors. Extinction rates. Oxford University Press, New York.

Mace, G. M., and R. Lande. 1991. Assessing extinction threats: toward a reevaluation of IUCN threatened species categories. Conservation Biology **5:**148–157.

McKinney, M. L. 1998. Is marine biodiversity at less risk? Evidence and implications. Diversity and Distributions **4:**3–8.

McKinney, M. L. 1999. High rates of extinction and threat in poorly studied taxa. Conservation Biology **13:**1273–1281.

Malmqvist, B., and S. Rundle. 2002. Threats to the running water ecosystems of the world. Conservation Biology **29:**134–153.

May, R. M., J. H. Lawton, and N. E. Stork. 1995. Assessing extinction rates. Pages 1–24 in J. H. Lawton and R. M. May, eds. Extinction rates. Oxford University Press, New York.

Okochi, I., H. Sato, and T. Ohbayashi. 2004. The cause of mollusk decline on the Ogasawara Islands. Biodiversity and Conservation **13:**1465–1475.

Pimm, S. L. 1991. The balance of nature? Ecological issues in the conservation of species and communities. University of Chicago Press, Chicago, Illinois.

Ponder, W. F. 2003. Endemic aquatic macroinvertebrates of artesian springs of the Great Artesian Basin—progress and future directions. Records of the South Australian Museum Monograph Series **7:**101–110.

Ponder, W. F., and D. Lunney. 1999. The other 99%: the conservation and biodiversity of invertebrates. The Royal Zoological Society of New South Wales, Mosman, Australia.

Powles, H., M. J. Bradford, M. R. Bradford, M. W. Doubleday, M. S. Innes, and C. D. Levings. 2000. Assessing and protecting endangered marine species. ICES Journal of Marine Science **57:**669–676.

Purvis, A., J. L. Gittleman, G. Cowlishaw, and M. G. Mace. 2000. Predicting extinction risk in declining species. Proceedings of the Royal Society of London—Biological Sciences **267:**1947–1952.

Radoman, P. 1985. Hydrobioidea, a superfamily of Prosobranchia (Gastropoda), II. Origin, zoogeography, evolution in the Balkans and Asia Minor. Faculty of Science, Institute of Zoology, Beograd, Serbia.

Reaka-Kudla, M. L. 1997. The global biodiversity of coral reefs: a comparison with rain forests. Page 450. Biodiversity II. Joseph Henry Press, Washington, D.C.

Robinson, D. G., and R. G. Hollingsworth. 2005. Report on the spread of the Cuban slug *Veronicella cubensis* (Pfeiffer 1840) in Guam, and Rota in the Northern Mariana Islands, and loss of molluscan biodiversity apparently resulting from introduced invasive gastropod species and the triclad flatworm *Platydemus manokwari* de Beauchamp, 1963. 71st annual American Malacological Society. American Malacological Society, Asilomar, Pacific Grove, California.

Rodrigues, A. S. L., J. D. Pilgrim, J. F. Lamoreux, M. Hoffmann, and T. M. Brooks. 2006. The value of the IUCN Red List for conservation. Trends in Ecology & Evolution **21:**71–76.

Strong, E. E., O. Gargominy, W. F. Ponder, and P. Bouchet. 2008. Global diversity of gastropods (Gastropoda; Mollusca) in freshwater. Hydrobiologia **595:**149–166.

Szarowska, M. 2006. Molecular phylogeny, systematics and morphological character evolution in the Balkan rissooidea. Folia Malacologica **14:**99–168.

Szarowska, M., and C. Albrecht. 2004. "Hydrobioid" localities in Greece: an urgent case for conservation. Tentacle **12:**14–15.

UNEP (UN Environment Programme). 1998. More isolated islands. UNEP, Geneva, Switzerland.

Whitten, A. J., S. V. Nash, K. D. Bishop, and L. Clayton. 1987. One or more extinctions from Sulawesi, Indonesia? Conservation Biology **1:**42–48.

Worm, B., et al. 2006. Impacts of biodiversity loss on ocean ecosystem services. Science **314:**787–790.