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The seven impediments in invertebrate conservation and how to overcome them

Pedro Cardoso [a,b,*], Terry L. Erwin [a], Paulo A.V. Borges [b], Tim R. New [c]

[a] Smithsonian Institution, National Museum of Natural History, 10th & Constitution NW, Washington, DC 20560, USA
[b] Azorean Biodiversity Group (CITA-A), Departamento de Ciências Agrárias, Universidade dos Açores, 9700-042 Angra do Heroísmo, Portugal
[c] Department of Zoology, La Trobe University, Bundoora, Victoria 3086, Australia

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ABSTRACT

Despite their high diversity and importance for humankind, invertebrates are often neglected in biodiversity conservation policies. We identify seven impediments to their effective protection: (1) invertebrates and their ecological services are mostly unknown to the general public (the public dilemma); (2) policy-makers and stakeholders are mostly unaware of invertebrate conservation problems (the political dilemma); (3) basic science on invertebrates is scarce and underfunded (the scientific dilemma); (4) most species are undescribed (the Linnean shortfall); (5) the distribution of described species is mostly unknown (the Wallacean shortfall); (6) the abundance of species and their changes in space and time are unknown (the Prestonian shortfall); (7) species ways of life and sensitivities to habitat change are largely unknown (the Hutchinsonian shortfall).

Numerous recent developments in taxonomy, inventorying, monitoring, data compilation, statistical analysis and science communication facilitate overcoming these impediments in both policy and practice. We suggest as possible solutions for the public dilemma: better public information and marketing. For the political dilemma: red-listing, legal priority listing and inclusion in environmental impact assessment studies. For the scientific dilemma: parataxonomy, citizen science programs and biodiversity informatics. For the Linnean shortfall: biodiversity surrogacy, increased support for taxonomy and advances in taxonomic publications. For the Wallacean shortfall: funding of inventories, compilation of data in public repositories and species distribution modeling. For the Prestonian shortfall: standardized protocols for inventorying and monitoring, widespread use of analogous protocols and increased support for natural history collections. For the Hutchinsonian shortfall: identifying good indicator taxa and studying extinction rates by indirect evidence.

1. The importance of invertebrates

Invertebrates dominate among multicellular organisms in terms of richness, abundance and often biomass; for example, more than 100,000 species of terrestrial arthropods occupy a single hectare of rain forest in the western Amazon (Erwin et al., 2004) and there is more ant biomass in the soils of the Serengeti Plains than there is of surface mammals (Hölldobler and Wilson, 1990). About 80% of all described species are invertebrates. Beetles alone comprise at least 10 times the number of species of all vertebrates together and over 25% of all described species. Invertebrates may be as small as 30–40 μm (male Cycliophorans, which have fewer than 60 cells on average (Neves et al., 2009)) or as large as 14 m (the colossal squid *Mesonychoteuthis hamiltoni*). They may be saprophagous, phytophagous, symbionts, parasites, endo and ectoparasitoids, even hyper-parasitoids, or the top predators of a long chain. They may be cosmopolitan, or present in extremely restricted distributions of a few hectares (e.g. some cave adapted species). They live on land, in fresh water, and in all the oceans of the world. With such richness of species and roles in all ecosystems, preserving the diversity of invertebrates, as of all other organisms, is a true life insurance for humankind. As eloquently noted by Wilson (1987), "If human beings were to disappear tomorrow, the world would go on with little change. (...) But if invertebrates were to disappear, I doubt that the human species could last more than a few months".

The ways human beings benefit from the conservation of invertebrates are hard to quantify and the general public is often unaware of them. A study by Costanza et al. (2007) calculated that global ecosystem services are valued at US$33 trillion per year, a large part of it directly or indirectly related with invertebrates. By 2050, biodiversity loss will be valued at 7% of the World's GDP (see: http://ec.europa.eu/environment/nature/biodiversity/economics/teeb_en.htm). In the United States alone, and with a conservative and partial estimate, ecological services provided by

* Corresponding author at: Azorean Biodiversity Group (CITA-A), Universidade dos Açores, Rua Capitão João d'Ávila, 9700-042 Angra do Heroísmo, Portugal. Tel.: +351 295 402 200; fax: +351 295 402 205.
E-mail address: pcardoso@ennor.org (P. Cardoso).

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insects annually were valued at US$57 billion (Losey and Vaughan, 2006).

In order to reiterate the importance of ecosystems and their constituent species to humankind, ecosystem services have been divided in four broad categories by the Millennium Ecosystem Assessment (2003, 2005): provisioning, regulating, cultural, and supporting services.

1.1. Provisioning services

These are related with the goods that humans can use and trade. Besides being or providing food (e.g. molluscs, bees), invertebrates yield many new pharmaceuticals and compounds or processes useful for technological and industrial purposes (see: http://www.wwf.org.au/publications/wwf-2010-and-beyond/), or may even be a target for mining activities (e.g. coral reefs).

1.2. Regulating services

These are related to the benefits of regulation of ecosystem processes provided by the different species. These services include pollination (e.g. of crop cultures), trophic regulation (e.g. pest control), or water purification (e.g. of ground waters by cave-obligate aquatic species).

1.3. Cultural services

These are non-material benefits. Invertebrates may serve as touristic attractions (e.g. coral reefs, butterflies), and many species are also essential model organisms for the study of biology, for example, the genetics of *Drosophila* and the many studies on increasing life-span performed with nematodes. In addition, many invertebrates are regularly used for environmental monitoring purposes (e.g. aquatic insects), as indicators of changes in the ecosystems that may not be felt as promptly in other taxonomic groups. Existence values are related with the willingness to pay for the conservation of species and communities (Martín-López et al., 2007). These are often prominent in flagship species, such as butterflies, dragonflies and corals, with which people may feel affinity or sympathy.

1.4. Supporting services

These are necessary for the production of all other ecosystem services and only indirectly impact on people's lives. Supporting services provided by invertebrates include nutrient cycling (e.g. dung burial, nitrogen volatilization), soil and ecosystem formation (e.g. aeration by tunneling, coral reefs) or as food source to other species (e.g. to commercial fisheries or game vertebrates).

2. The neglect of invertebrates

One of the major crises Earth's ecological stability faces today is the ever-growing and accelerating mass extinction of species due to human activities (Erwin, 1991a; Lawton and May, 1995; Purvis and Hector, 2000; Smith et al., 1993). Our knowledge of global biodiversity and its rate of extinction is very limited, but of the 3–100 million species believed to exist, conservative estimates point to about 3000 being lost each year, that is, eight species per day (Wilson, 2003a; González-Oreja, 2008). The vast majority belongs to understudied taxa such as certain groups of invertebrates, "the little things that run the world" (Evans, 1993; Wilson, 1987). They are subject to the same extinction processes as larger and more familiar organisms, plus a few additional ones, such as co-extinction and extinction of narrow habitat specialists (Dunn, 2005; Dunn et al., 2009). When corrected for knowledge bias, data from invertebrates show even higher extinction rates and proportions of threatened species than those of well-known taxa such as birds and mammals (MacKinney, 1999; Moir et al., 2010; Stork and Lyal, 1993; Thomas and Morris, 1994). Nevertheless, only 70 species have been officially reported extinct for the last 600 years (Dunn, 2005), all others having vanished before discovery or description, the so-called Centinelan (Wilson, 1992) or Linnean extinctions (Cardoso et al., 2010; Ladle and Jepson, 2008; Régnier et al., 2009; Triantis et al., 2010).

The loss of species often implies the loss of functional diversity and the provision of ecosystem services, with consequences to human well-being (Section 1; see a review in Balvanera et al., 2006). The loss of pollinators may cause the loss of productivity in many crops (Kremen et al., 2002; Kremen and Ostfeld, 2005); the loss of predators and parasitoids in agricultural fields may cause the loss of ecosystem capacity to control pest outbreaks and the consequent loss in productivity (Landis et al., 2000; Symondson et al., 2002); the loss of groundwater fauna may cause the disruption of purification and bioremediation processes and consequent pollution problems (Boulton et al., 2008); the loss of coral reefs may cause diminishing returns from tourism (Moberg and Folke, 1999); among many other examples.

Despite their high diversity and importance for humankind, invertebrates have largely been neglected in conservation studies and policies worldwide (Cardoso et al., in press; Kremen et al., 1993; New, 1999; Zamin et al., 2010). Reflecting this neglect, the World Conservation Union's (IUCN) Red List of Threatened Species (IUCN, 2010) lists less than 0.5% of all described arthropods and 4% of all described molluscs worldwide (Fig. 1), when most vertebrates have already been assessed. Of all the species evaluated, the endangered categories occupy similar if not higher proportions than comparable numbers for vertebrates (Fig. 1). Even if such proportions are inflated by the evaluation of species thought *a priori* to be endangered, the increases are countered by the vast numbers of undescribed species that mostly have restricted distributions and have not yet been collected or diagnosed (Gaston, 1994). National red lists follow the same trend, with invertebrates being among the taxa with the least comprehensive coverage in countries worldwide (Zamin et al., 2010).

Even in areas such as Europe where invertebrate species are relatively well known (Fig. 2a; Schuldt and Assmann, 2010), the support given to their conservation is markedly inappropriate considering their role in ecological processes upon which a healthy planet and human welfare depend (Leather, 2009). The largest funding program for the conservation of species and habitats in Europe is the LIFE–Nature program. Justification for funding is largely based on the priority lists of the Habitats and Birds Directives. Because such lists are markedly biased towards some well-known taxa, funding is equally biased (Fig. 2b; see also Cardoso, in press). On average, each arthropod species received 1000 times less funding for its conservation than each mammal species (Fig. 2c).

Contradicting the low level of conservation support given to invertebrates, when evaluated in equal stance to vertebrates, they rank high in conservation priority lists. In a recent resource allocation exercise for the Macaronesian archipelagos (Martín et al., 2010), using unbiased criteria to rank almost every insular taxon, invertebrates constituted more than twice the number of vertebrates among the highest ranking species. This was in a rank largely dominated by plants, which are also remarkably underrepresented in most conservation efforts (Figs. 1 and 2). In the Azores, where invertebrates have been thoroughly studied (Borges et al., 2005; Cardoso et al., 2007; Gaspar et al., 2008, in press; Triantis et al., 2010), more so than in the other archipelagos and most other regions worldwide, they constituted more than half of all priority species (Martín et al., 2010).