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An introduction to the Freshwater Animal Diversity Assessment (FADA) project

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Abstract The Freshwater Animal Diversity Assessment (FADA) project aims at compiling an overview of genus- and species-level diversity of animals in the continental, aquatic ecosystems of the world. It is a collective effort of 163 experts, and presents 59 articles treating the diversity and endemism of different animal taxa, ranging from microscopic worms to mammals, at global and regional scales. Given their structural importance, an article on macrophytes is also added. Here, we give an overview of the project's history, and outline the common framework of the various articles, as well as the conventions the experts agreed to adhere to in their treatises. Furthermore, we briefly introduce future prospects.

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Freshwater Animal Diversity Assessment

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Introduction

Notwithstanding decades, if not centuries, of taxonomic and faunistic work, it remains difficult to obtain a global overview of biodiversity of freshwater ecosystems. Available knowledge on the matter was never thoroughly compiled and is largely scattered, localised and focuses on a few well-studied groups. Consequently, answering the simple question: "How many species are there in the freshwaters of the world, on continents or in major biogeographic regions?" remained difficult. In addition to constituting relevant basic scientific knowledge on freshwater biodiversity, such an estimate would be a valuable tool for conservation purposes in the face of increasing pressure on freshwater ecosystems. Indeed, more and more evidence documents the major crises faced by biodiversity and biological resources of inland waters, and which are directly correlated to water resource integrity (Postel & Richter, 2003). In addition to their intrinsic value, freshwater ecosystems provide essential goods and services to humankind (Postel & Carpenter, 1997), especially in the third world communities that traditionally depend directly on the availability of natural resources.

Drawing a global picture of freshwater biodiversity has not raised much interest, mainly because of the peculiarities of freshwater habitats. Their island-like nature complicates a global approach, and most taxonomists are overwhelmed by local faunas, especially when studying the highly diverse communities inhabiting ancient lakes or the diversity of groundwater fauna. However, the recognition of changes at a global scale and their impact on freshwater ecosystems (Dudgeon et al., 2006) as well as the need to stop the loss of freshwater biodiversity, motivated the Convention on Biological Diversity (CBD) to support global assessments of status of and trends in freshwater biodiversity, for example Groombridge & Jenkins (1998, 2000) and Revenga & Kura (2003). However, till now, no exhaustive literature review had been performed across all taxonomic animal groups, and a more extensive approach was required to provide information on the diversity and distribution of freshwater species and genera of the world. The Freshwater Animal Diversity Assessment (FADA) project took up the challenge of compiling this information. At the same time, a global assessment was completed on macrophyte diversity, as vascular plants play a key role in structuring the habitat of, and providing food to, many freshwater animals.

In this article, we present a short history of the FADA project, describe its specific objectives, and the common standards and agreements the different FADA experts accepted in order to maintain coherence between the 59 articles of this special issue.

History of the FADA project

Previous assessments

In conjunction with the CBD, some prior attempts to estimate the number of freshwater organisms, and to identify priority areas for conservation, have been made, although these mostly focused on some better-known groups (Groombridge & Jenkins, 1998, 2000; Revenga & Kura, 2003). The latter paper not only compiled a wide range of information on water resources, water system characteristics, threats and conservation aspects, but also included a fairly detailed report of taxonomic diversity for many freshwater taxa. In addition, Revenga & Kura (2003) highlighted the need for additional work on species diversity and distribution in order to better define conservation priorities.

Toward a global assessment of freshwater animal diversity

A preliminary phase of the FADA project lasted from September 2002 to June 2003 and received support from DIVERSITAS and the "Centre National pour la Recherche Scientifique"—French National Research Institute (CNRS). The main objective was to produce a discussion document that identified gaps in our knowledge of freshwater biodiversity, and could be used to triggering experts reactions (Lévêque et al., 2005). This first study led to a gross estimate based on existing databases, published reviews and contacts with taxonomists. The study estimated that known freshwater animal species diversity worldwide was in the order of magnitude of 100,000, half of these being insects. Among other groups, some 20,000 vertebrates; 10,000 crustaceans and 5,000 mollusc species were reported as truly aquatic or water-dependent species.

The preliminary study highlighted gaps in the basic knowledge of species richness at continental and global scales:

1. Some groups such as freshwater nematodes or annelids are understudied and data on their diversity and distribution is scarce. Because current richness estimates for such groups are greatly biased by knowledge availability, we can expect real species numbers to be much higher;
2. Research intensity in the different zoogeographic regions is unbalanced: reliable regional estimates of diversity on the Neotropical and the Oriental regions are lacking for many groups, even for some usually well-known ones such as molluscs or insects.

In addition, the preliminary study of Lévêque et al. (2005) generated numerous comments from the taxonomic community, highlighting that certain key data had not been included. We welcomed these comments by inviting the concerned taxonomic experts to join efforts in the consecutive phase of the project.

Implementation of the FADA project

The Belgian Science Policy (BelSPO), the Belgium Biodiversity Platform and the Royal Belgium Institute of Natural Sciences (RBINS, Brussels, Belgium) provided the necessary support to launch the "Freshwater Animal Diversity Assessment" project in March 2005. Taxonomic experts were invited to join a team of authors to write an article on the diversity of each animal group. These coordinating authors participated in a workshop during which they presented the data on their taxonomic group, and together discussed standards of a common approach (October 13–16, 2005). The resulting reviews are included in the present special issue of *Hydrobiologia*.

As mentioned before, the main goal of FADA is to provide an expert assessment of animal species diversity in the continental (fresh) waters of the world, focusing on taxonomic and biogeographic diversity. The main three objectives for each group are:

1. to give an as accurate as possible estimate of global species and generic diversity;
2. to report on geographic distribution (by zoogeographic region, as described below), and to identify possible gaps;
3. to highlight the main areas of endemicity.

Because extant patterns are the results of historical processes, the project also emphasises phylogenetic aspects and processes of evolution and speciation. In addition, information on human-related issues, such as economical and medical uses, threats, conservation issues, is included when pertinent.

Characteristics of this special issue

Our assessment aims to cover the whole range of freshwater taxa from sponges and nematodes or bryozoans to mammals and birds, including a specific article on macrophytes, but excluding microbes, virus, protists, and algae. In addition, all groups, which are exclusively parasitic and not entirely aquatic are also excluded[1] (i.e., Acanthocephala, Monogenea, Digenea and others); a total of 59 groups/articles are included in this issue. Some articles address a whole Phylum (Rotifera, Porifera...), other papers address a class, an order or even a family, depending on factors like the number of species concerned, level of knowledge on the taxon, available expertise, or historical treatment of the taxon. For instance, an article addressing a relatively species-poor taxon (i.e., Halacaridae), has nevertheless been included, as little comprehensive information had previously been published. On the other hand, the insect order Diptera, is far too diverse, both in number of species and ecology, to be treated in a single article. Consequently, key freshwater families are treated in separate articles (Chironomidae, Culicidae, Simulidae, Tipulidae), and one article addresses the remaining Diptera families. Only the family Tabanidae is not included, as no global expertise appeared to be available.

Article framework

Strict space limits, especially regarding references, were imposed on the authors in order to achieve a single-volume compilation: for each article, space was allocated according to an initial estimate of the diversity of the concerned taxon. A model article framework was imposed to ensure that all standard, required data and information be included, and to maintain coherence amongst reviews, as well as to allow analyses of the data across all taxa.

1. As the main focus of these compilations is not on biology or ecology, only a brief summary of these aspects and some key references are provided in the introduction of each article.
2. The first and main section of each contribution is the "*species and generic diversity section*", which provides information on the known number of species and genera, per relevant higher-level taxon (family, subfamily...). Depending on the group, optional material in this section includes diversity of higher taxa, diversity of groups in selected habitats, data on fossil diversity and estimates of unknown diversity. Only the Gastropoda and the Coleoptera sections do not provide data on generic diversity, but the respective authors provide their arguments for not submitting this information.

[1] Micrognathozoa, a monotypic taxon of moss-dwelling microscopic organisms of which only two disjunct records exist (Disco Island, Greenland and the subantarctic Crozet Islands: De Smet, 2002), is not treated in a full article.

3. The second, optional, section deals with "*phylogeny and historical processes*". Most articles include a brief treatise on evolutionary origin, age, and history of the group. Supplementary information can be added on speciation and diversification processes over time in various areas of the world, and on morphological and molecular phylogenies. Some authors address the main drivers of change: natural and anthropogenic processes of selection and the factors influencing spatial and temporal changes in the genetic stock, in population size, and/or regarding habitat fragmentation.
4. The following, compulsory section on "*Present distribution and endemicity*" provides synthetic maps of species and generic diversity at the level of the main zoogeographical regions (Palaearctic, Nearctic...). The section can include reports on historical patterns and processes, e.g., how the break-up of Gondwana contributed to the present-day distribution. In addition, authors report on endemicity at the species and genus level, and identify hotspots of endemicity.
5. Finally, in a last optional section, "*Human-related issues*" are discussed. This deals with the (potential) economic or medical relevance of the taxon treated, its relevance to fundamental or applied research, or concern for conservation, e.g., IUCN's Red Data Book species, special reserves established or needed, and main threats.

Changes to this framework were allowed for short articles in which it was more logical to address species diversity and distribution together, especially if the optional section on phylogeny was not included.

Terminology

To ensure coherency and homogeneity between articles, the different experts agreed to adhere to common concepts and definitions. An overview of these is as follows.

1. Hotspot: This term is used in relation to richness or endemicity, however, not necessarily with reference to specific threats. In this we deviate from the definition by Myers et al. (2000), in which the term is used in relation with threats and conservation priorities.
2. Endemism/Endemicity: Use of these terms should always include a reference to the relevant geographical unit. In general, endemicity is discussed in relation to the main biogeographic units as defined below. In some cases, endemicity is treated regarding circumscribed local areas, such as Lake Baïkal, Lake Victoria, the Mississippi drainage, or others.
3. Cosmopolitan species: A taxon is considered cosmopolitan if it is present in all zoogeographical regions except Antarctica, unless stated otherwise.
4. Regarding terms related to conservation issues authors refer to the IUCN categories and the IUCN Red list (IUCN, 2006). For example, the term "extinct" is used only in the situation where no more living specimens exist on earth, versus "extirpated" indicating that a taxon or population has disappeared locally.
5. Aquatic and water-dependent species: Defining what exactly constitutes a freshwater species proved to be controversial. For practical reasons, we limited ourselves to non-marine species of inland waters in two categories:

   (1) The 'real aquatic species' accomplish all, or part of their lifecycle in, or on, water.
   (2) "Water-dependent" or "paraquatic" species show close/specific dependency upon aquatic habitats (e.g., for food or habitat). Limno-terrestrial species, i.e., species that require an aqueous matrix in strictly terrestrial habitats for active life, like the water film retained by some mosses, are not included in the total numbers. However, they can be discussed in the article when considered pertinent by the expert.

   For some groups, attributing taxa to these ecological categories (water-dependent, limno-terrestrial and terrestrial) turned out to be particularly difficult, mostly owing to a lack of information on life history or ecological requirements of the taxa concerned. Authors were asked to argument their decision on the inclusion or omission of taxa in the total count.
6. Fresh and brackish water species: While the present assessment focuses on diversity of non-marine taxa, a number of thalassic or athalassic

brackish water ecosystems are nevertheless considered. Regarding interface environments (estuaries, anchialine ponds), only the non-marine fauna is included from such habitats. Euryhaline species in estuaries are included in the record, if they show a genuine tolerance to freshwater (<3 g/l). Species that are restricted to such interface environments, and that are therefore absent from both purely marine or fresh waters are not normally included in the total count of freshwater taxa. These cases are specifically addressed in the separate articles, and they can be recorded separately, according to the relevant expert's judgement.

7. Geographical distribution: zoogeographical regions: Regarding the global distribution, reference is made to standard zoogeographic regions as defined in classic textbooks (e.g., Wallace 1876; Cox 2001). We acknowledge that it is impossible to strictly delineate the world's major biogeographic regions. Issues were raised regarding the transitional zone between the Palaearctic and Oriental regions in China and India, the limits between the Oriental and Australasian regions, and the Mexican plateau between the Nearctic and Palaearctic regions. For standardisation purposes, we use the following names and delineations for regions (Fig. 1):

- The *Palaearctic Region (PA)* consists of Europe and Russia, North Africa (not including the Sahara) and Northern and Central Arabian Peninsula, Asia to south edge of Himalayas.
- The *Nearctic Region (NA)* consists of North America, Greenland and the high-altitude regions of Mexico.
- The *Afrotropical Region (AT)* consists of Africa south of the Sahara, the Southern Arabian Peninsula and Madagascar.
- The *Neotropical Region (NT)* consists of Southern and coastal parts of Mexico, Central America, and the Caribbean islands together with South America.
- The *Oriental Region (OL)* consists of India and Southeast Asia south of Himalayas (including lowland southern China) to Indonesia down to the Wallace's Line. It extends

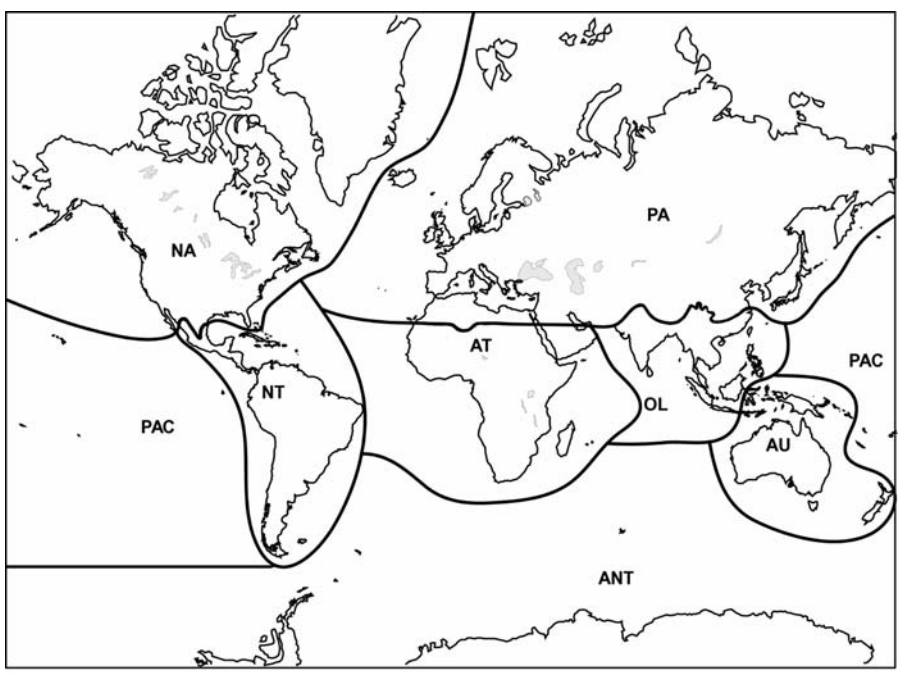

Fig. 1 Standard map of the zoogeographical regions. PA: Palaearctic Region, NA: Nearctic Region, AT: Afrotropical Region, NT: Neotropical Region, OL: Oriental Region, AU: Australasian Region, ANT: Antartic Region, PAC: Pacific Region and Oceanic Islands

through Indonesia as far as Java, Bali, and Borneo to Wallace's line, and includes the Philippines, lowland Taiwan and Japan's Ryukyu Islands.

- The *Australasian Region (AU)* consists of Australia and New Zealand, New Guinea including Papua New Guinea and the Indonesian province of Papua, and Indonesian Islands south and east of Wallace's Line. It includes the island of Sulawesi, the Moluccan islands (the Indonesian provinces of Maluku and North Maluku) and islands of Lombok, Sumbawa, Sumba, Flores, and Timor.
- The *Antarctic Region (ANT)* includes the Antarctic continent and the Antarctic and subantarctic islands south of the Antarctic convergence.
- *The Pacific Region and Oceanic Islands (PAC)*: includes the islands in the North and South Pacific ocean, with the Bismarck Archipelago, Vanuatu, the Solomon Islands, and New Caledonia.

In the few cases where experts were unable to clearly attribute a taxon to a specific region, arguments are listed in support of the final decision on the matter.

Conclusion

This is the first publication of the FADA project, and we are convinced that the information it contains will prove to be useful. In parallel to the production of this work, we are developing a database in which the taxonomic and distributional data on which the treatments presented here are based. This on-going task aims not only to provide access to the raw data the FADA experts have compiled, but we envisage developing a web portal containing additional functionalities like, for example, a repository for local distributional data (see Segers, 2007). These services and any supplementary information resulting from the project will be made accessible through http://www.fada.biodiversity.be (Balian et al., 2007).

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