diversity

Editorial

Introduction to the Special Issue "Aquatic Insects: Biodiversity, Ecology, and Conservation Challenges"

Marina Vilenica [1,*], Laurent Vuataz [2,3,*] and Zohar Yanai [4,*]

[1] Faculty of Teacher Education, University of Zagreb, Trg Matice Hrvatske 12, 44250 Petrinja, Croatia
[2] Museum of Zoology, Palais de Rumine, Place de la Riponne 6, 1014 Lausanne, Switzerland
[3] Department of Ecology and Evolution, University of Lausanne (UNIL), 1015 Lausanne, Switzerland
[4] The Steinhardt Museum of Natural History, Tel Aviv University, Tel Aviv 6997801, Israel
* Correspondence: marina.vilenica@ufzg.hr (M.V.); laurent.vuataz@vd.ch (L.V.); yanai.zohar@gmail.com (Z.Y.)

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In non-marine environments, insects comprise one of the most species-rich and abundant groups of organisms. They have always been the focus of scientific attention on freshwater habitats, such as streams, rivers, lakes, and ponds. Although such habitats cover only 2.3% of the Earth's surface, they accommodate approximately 10% of all known animal species, and represent "hotspots of endangerment" due to disproportionally high biodiversity and anthropogenic pressures [1]. More than 60% of the freshwater species diversity is represented by aquatic insects, with approximately 130,000 described extant species [2–4]. They spend one or more stages of their life cycle in aquatic habitats, with the majority moving to terrestrial areas as adults. Members of the orders Ephemeroptera, Plecoptera, Trichoptera, Megaloptera and Odonata are exclusively aquatic in their immature stages (i.e., nymphs and larvae). Several other insect orders, such as Diptera, Coleoptera, Neuroptera, and Hemiptera also have many aquatic representatives [3,4].

Aquatic insects have important ecological roles in both aquatic and terrestrial habitats as primary consumers, detritivores, and predators. Moreover, they dominate in terms of biomass and productivity, representing an important food resource for a vast number of aquatic and terrestrial, both invertebrate and vertebrate, predators. Therefore, they represent an important link in food and energy transfer from aquatic to terrestrial ecosystems [4]. The composition and structure of their communities are closely related to habitat type, abiotic parameters (e.g., water temperature, water depth, water velocity, oxygen content, pH), predation, microhabitat (substrate) composition, and available food resources. Many aquatic insects, such as mayflies, stoneflies, and caddisflies, have shown to be highly sensitive to anthropogenic alterations in their habitats and have been widely used as valuable taxonomic groups for biomonitoring programs worldwide [5]. Some aquatic insects, such as mosquitoes, have been well-studied due to their important role as disease vectors [6]. In a more anthropocentric view, many aquatic insects are crucial for the provision and support of various ecosystem services (e.g., [7]). Although the efforts of aquatic entomologists tremendously increased during the 21st century, much is yet undiscovered. Our knowledge about aquatic insects is still far from being complete, both in natural systems, such as springs, rivers, streams, lakes, but also in artificial habitats, such as irrigation canals and man-made reservoirs.

The current Special Issue addresses all aspects of biodiversity of aquatic insects, including taxonomic diversity and phylogeny, distribution patterns, and community ecology. In addition to increasing fundamental knowledge, such data are crucial for understanding the importance of anthropogenic disturbances and mitigating their unknown impacts. In a context of rapid global biodiversity loss, encouraging signals, such as the upward trend in the abundance of freshwater insects in some regions, have recently been detected [8]. Past efforts to improve water quality and restore habitats, which most probably explain part of this positive trend, should motivate the scientific community to become even more involved in describing, understanding, and protecting freshwater ecosystems in the future.

Most of the important insect orders with aquatic representatives are represented in this Special Issue (Figure 1). Geographically speaking, the papers published here represent almost all continents and almost all biogeographical realms (Figure 2). Aquatic entomology is widely investigated in Australia, Europe, and North America. The trends reflected here indicate an increasing interest in certain African and Asian countries. This is mainly due to the efforts of local research groups, highlighting the importance of training and supporting scientists in additional countries.

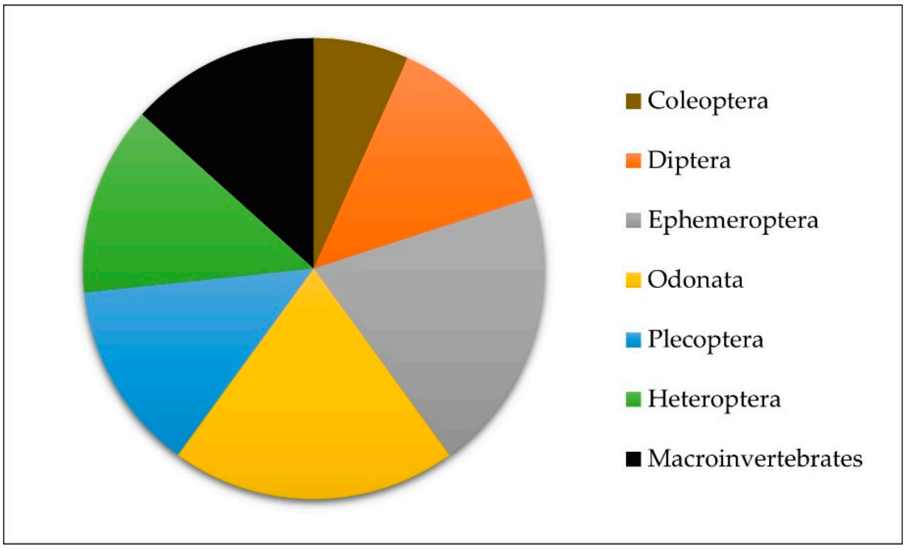

Figure 1. Aquatic insect orders investigated in studies published in the *Diversity* Special Issue: Aquatic Insects: biodiversity, ecology, and conservation challenges.

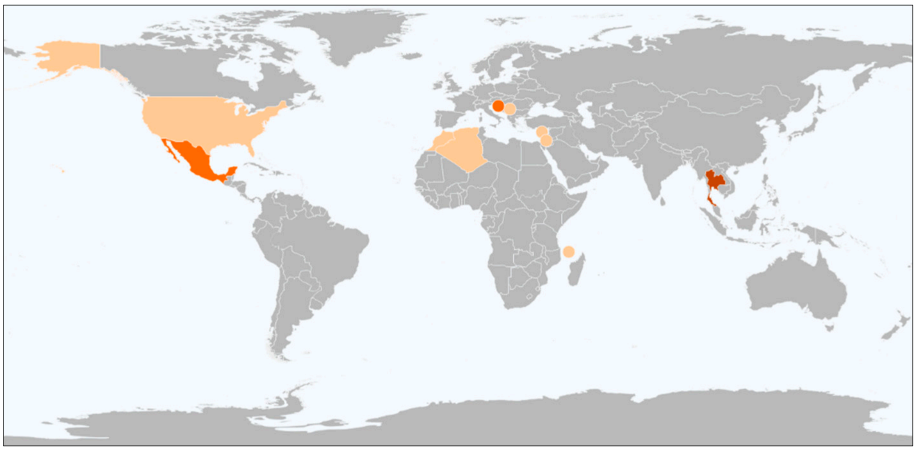

Figure 2. Distribution of contributions to the Special Issue. Colored countries are represented in the Special Issue; color shade represents the number of contributions from a country (light—1, dark—3).

The most speciose aquatic insect orders, Coleoptera and Diptera, are represented with only one [9] and two contributions [10,11], respectively. Studying the aquatic Coleoptera, the authors have reviewed the *Laccophilus alluaudi* species group from the Comoro Islands, and recognized five species, out of which four were newly described [9]. Both publications regarding the aquatic Diptera focused on the very diverse but still relatively poorly investigated family Chironomidae in southeastern Europe. One study investigated the diversity of periphytic Chironomidae in a floodplain aquatic ecosystem and revealed a high dependency of diversity of chironomid assemblages on substrate type, where the highest diversity was recorded on macrophytes [10]. The other study investigated Chironomidae assemblages in urban water bodies, which showed relatively high diversity but also different tolerance levels of chironomid taxa to environmental pressures recorded in such aquatic systems [11].

Relatively small orders of aquatic insects, Ephemeroptera [12–14] and Odonata [15–17], are represented with three papers each. New data about the diversity and distribution of Moroccan mayflies are presented. Currently known Moroccan mayfly fauna consists of 54 species and is characterized by a clear dominance of Mediterranean groups with a strong rate of endemism [12]. Phylogenomic analyses of the family Coloburiscidae, which consists of three extant genera with a Gondwanan distribution (*Coloburiscoides* from Australia, *Coloburiscus* from New Zealand, and *Murphyella* from Chile), confirmed its monophyletic origin [13]. The third publication on mayflies resolved the taxonomy, distribution, and life cycle of the Maghrebian endemic mayfly species, *Rhithrogena sartorii* in Algeria [14]. Taxonomy and distribution were investigated for the gomphid dragonfly species, *Orientogomphus minor* from Thailand, where the nymph was described for the first time, and the male specimen was re-described and illustrated [15]. A checklist of Odonata from Cyprus revealed 37 species, among which some have a very restricted distribution range, such as *Ischnura intermedia* [16]. An ecological study on Odonata of Mediterranean intermittent rivers revealed the importance of aquatic vegetation structure and composition of Odonata assemblages, which were shown to be species-rich in such habitats, with 22 recorded species [17].

Another small aquatic insect order, Plecoptera, was investigated in two publications [18,19]. In the first publication, the stonefly diversity was investigated in Indiana, USA, and revealed 93 species. Plecoptera species richness in the study area was highly influenced by hydrology and glacial history [18]. The Israeli stonefly fauna is extremely species-poor, and historically, only five species were recorded. In the study published in this Special Issue, a strong decrease in stonefly occurrence was observed. The populations of three species have dramatically declined in recent decades (*Protonemura zernyi*, *Leuctra hippopus*, and *Leuctra kopetdaghi*), whilst the remaining two species (*Brachyptera galeata* and *Marthamea beraudi*) have not been collected at all in over four decades and are considered locally extinct [19].

Aquatic Heteroptera, a species-rich but poorly known insect order, was the focus of two publications, both from the same research group [20,21]. The first publication investigated the aquatic (Nepomorpha) and semiaquatic (Gerromorpha) Heteroptera assemblages in three streams within the Kaeng Krachan National Park in Thailand. The study revealed high species richness, with 60 recorded species [20]. Both mangrove ecosystems, and their biota, are still poorly known. The second publication investigated Gerromorpha assemblages in mangroves located in the central and eastern regions of Thailand and recorded a total of nine species, four of which were new records for the country [21].

In many ecological studies, aquatic insects are sampled and analyzed within the entire macroinvertebrate community. Indeed, two papers adopted a wider perspective and examined the macroinvertebrate community in freshwater habitats of Central America (Mexico) [22,23]. The first publication investigated water quality analysis in a subtropical river using a newly created adapted biomonitoring working party index based on macroinvertebrate communities [22]. The second, and the last publication within this Special Issue, investigated aquatic macroinvertebrates in a biosphere reserve, at sites encompassing different impact and human influence scenarios. The results emphasize the importance of the relationships between the functional macroinvertebrate diversity indices and the physicochemical parameters as well as the environmental indices measured within the study area [23].

The overview of this Special Issue perhaps highlights, in a nutshell, important knowledge gaps in the field of aquatic entomology. Better distribution of taxonomic and geographical foci should be considered in future studies.

Conflicts of Interest: The authors declare no conflict of interest.

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