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Editorial: Aquatic insect ecology in a changing world

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Editorial on the Research Topic
Aquatic insect ecology in a changing world

The overarching goal of this Research Topic was to serve as an outlet for studies on the impacts of a changing environment on aquatic insects. For example, how can aquatic insect data answer fundamental questions about watershed health, biotic integrity, and other aspects of freshwater ecosystems? Numerous anthropogenic pressures (Figure 1) affect insect communities around the globe, including habitat loss and fragmentation, organic and inorganic pollution, the spread of invasive species, dams and diversions, global climate change, and urbanization, among many others. These pressures lead to many negative and pervasive impacts, from the complete extinction of species, to losses of aquatic insect biomass, changes in the relative abundance of different feeding groups, and subtle decreases in species fitness, all of which can be harbingers of more damaging impacts in the future (Figure 1) (Cardoso et al., 2020).

Despite their cryptic nature, the ecological importance of aquatic insects is overwhelming. These organisms represent approximately 10% of the known insect fauna and span every continent except Antarctica (Hotaling et al., 2020). They occupy primarily lentic and lotic surface freshwaters, as well as occasional marine and brackish environments, cave systems, the hyporheic zone, and terra firma. Aquatic insects provide innumerable ecological services to humanity and serve as important trophic links in aquatic food webs. In addition, they are of great interest to ecologists, evolutionary biologists, naturalists, and the fly-fishing community. Their ubiquity, diversity, and spectrum of responses to natural and anthropogenic pressures render aquatic insects invaluable indicators of freshwater health and changing environments.

Several recent studies have suggested that the planet is experiencing a human mediated ‘insect apocalypse’, with aquatic insects disproportionately affected both in terms of species extinctions (Sánchez-Bayo and Wyckhuys, 2019) and changes to their community structure (Greenop et al., 2021). Simultaneously, ongoing human conflicts over water use, with corresponding degradation of aquatic habitats, continue to be a global problem (Feio et al., 2022). Because of their dependence on freshwater, aquatic insects can provide critical information on how a changing world affects such ecosystems.

We intentionally took a wide-ranging approach when soliciting papers for this Research Topic, as we wanted research that addressed the various pressures and impacts (Figure 1) affecting aquatic insects. This approach culminated in a Research Topic treating various topics

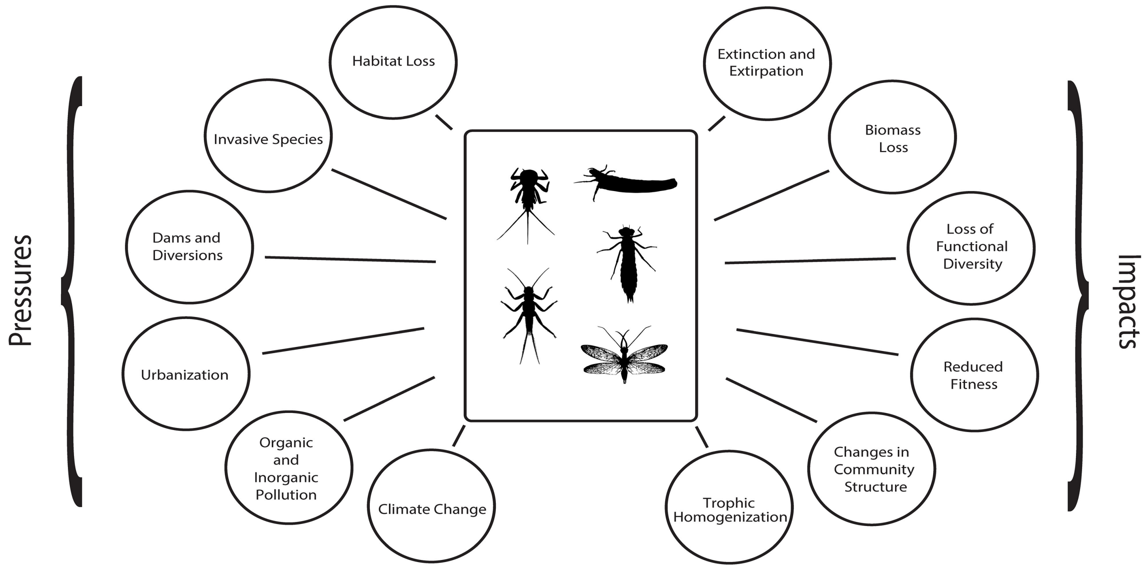

FIGURE 1
Select pressures (left) on aquatic insects and their impacts (right). Note that these pressures can act synergistically and lead to multiple outcomes across spatial, temporal, trophic, and taxonomic scales.

of aquatic insects' interactions with a rapidly changing world, and spanning different taxa and scales.

First, Cochran et al. investigated the life-history and physiological responses of a mayfly (Ephemeroptera) to saltwater intrusion, an increasing problem in many of the world's coastal areas. The authors concluded that those populations of the mayfly *Callibaetis floridanus* Banks, 1900 subject to saline conditions face higher energetic demands than those populations existing in non-saline habitats. Thus, the pressure of inorganic pollution will likely lead to the impact of reduced fitness.

A second paper also dealt with mayflies and simultaneously treated stoneflies (Plecoptera), evaluating morphological changes along an elevation gradient. Rendoll-Cárcamo et al. modeled body size and wing length based on hundreds of specimens representing 10 species. They found a general increase in body size and a decrease in wing size along the elevation gradient and over a relatively short geographic distances, demonstrating morphological plasticity in response to harsh sub-Antarctic conditions. The implications of these findings are particularly interesting in the context of the pressure of climate change and the unpredictability of its impacts on different species.

Shifting to the most diverse primary aquatic insect order, the caddisflies (Trichoptera), Houghton and DeWalt analyzed a dataset of nearly half a million specimens, comprising 282 species, and collected from almost 800 streams of the northcentral United States. They used 18 predictor variables representing natural habitat conditions, anthropogenic disturbance, and weather differences to model species richness in the region. Alarmingly, the authors found that the anthropogenic pressure of upstream terrestrial habitat loss—not natural environmental variation—was the primary driver of species richness differences in streams throughout the study area, and that the impact of extirpation was widespread, with 60% of modeled streams having lost more than half of their historical species richness.

Taking a broader taxonomic approach, Robinson used large EPT (Ephemeroptera, Plecoptera, and Trichoptera) datasets to evaluate the effects of taxonomic resolution on the ability to effectively describe ecological patterns relevant to the conservation of aquatic insect species. The author found that the current family- and genus-level identification schemes used in aquatic biomonitoring fail to adequately capture the information required to make informed freshwater macroinvertebrate conservation decisions. Thus, using aquatic insects to assess anthropogenic pressures necessitates identifying to the species level to properly understand the impacts of extinctions and extirpations.

Finally, a review paper by Ferzoco et al. examined the state of knowledge of freshwater insects in urban environments. The urbanization of streams involves several anthropogenic pressures, including habitat loss, pollution, dams and diversions, as well as additional pressures unique to urbanization, such as a high prevalence of impervious surface and extreme runoff events. Thus, this land use is likely to lead to the greatest number of impacts on aquatic insects. The authors, unfortunately, noted significant European and North American bias in urban stream studies, underrepresentation of lentic systems relative to lotic systems, and a lack of consistent impacts based on available data. Clearly, much work has yet to be done in investigating urbanization's impacts of freshwater systems.

It is apparent that the ongoing loss of aquatic insect biological and ecological diversity makes these animals' study particularly timely. The Research Topic here provides a small but diverse sampling of our collective efforts to understand the ongoing impacts on aquatic insects by the anthropogenic pressures of an ever-changing world. While much information remains to be discovered, it is clear from our sample of papers that anthropogenic pressures are currently causing significant, widespread, and lasting impacts on aquatic insect populations, species, and communities. We hope that the information presented here will serve to both inform current science and policy, and act as a springboard for the many studies needed to better understand this massive, important, and evolving area of study.

Author contributions

AO: Conceptualization, Project administration, Supervision, Validation, Visualization, Writing—original draft, Writing—review & editing. DH: Conceptualization, Project administration, Supervision, Validation, Visualization, Writing—review & editing. JR: Conceptualization, Project administration, Supervision, Validation, Writing—review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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