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INTRODUCTION

Amphipod disease: model systems, invasions and systematics — Introduction to DAO Special 8

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ABSTRACT: Amphipods are a group of globally abundant Crustacea present throughout terrestrial, marine and freshwater ecosystems. These organisms host a highly diverse systematic assemblage of parasites and pathogens, which are closely linked to the host's evolution and ecological niche. Such symbioses have been found to affect the behaviour, physiology and overall health of amphipod hosts; including effects at both the individual and population scale, altering aquatic trophic structure and possibly representing far reaching consequences for fisheries species and predatory species. Amphipod diseases explored in this Special have been linked with biological invasions, systematics, behavioural ecology, ecotoxicology, epidemiology, host physiology and cannibalistic tendencies. These studies exemplify the importance of amphipod research and provide keystone studies for the use of these animals as model systems for understanding the effects of disease in crustacean assemblages.

KEY WORDS: Amphipoda · Ecotoxicology · Macroparasite · Microparasite · Taxonomy · Ecology

The Amphipoda (Peracarida) consists of over 10000 species across aquatic and terrestrial habitats on a global scale. These crustaceans are host to multiple symbionts, including viruses, bacteria, Microsporidia, Fungi, Protozoa, rotifers, trematodes, acanthocephalans, nematodes, cestodes and crustaceans (reviewed in Bojko & Ovcharenko 2019). Their coevolutionary link to this wide diversity of symbionts suggests that amphipods could be a versatile model system for understanding the effects of multiple symbioses, including parasitism. This Special highlights multiple examples of how amphipods and their diseases have been used to explore the relation between disease and animal behaviour, biological invasions, environmental ecotoxicology and systematics. In each example, amphipod hosts were used to provide novel and detailed information applicable to better understanding the dynamics of disease.

Diseases are omnipresent throughout an organism's evolutionary history. Disease can dictate whether an animal lives or dies, it can alter behaviour, and it can result in physiological change. These aspects of direct or indirect effects of diseases are explored in experiments with amphipods by Arundell et al. (2019a,b). Their results show that trematode parasites affect the behaviour, fecundity and physiology in the amphipods *Gammarus zaddachi* and *G. duebeni*. In these hosts, their anatomy is altered to deviate from its natural symmetry, resulting in an asymmetrical animal, which may impact its ability to mate and survive.

During biological invasions, a non-native host population moves to a novel location, in many cases coinvading with multiple symbionts. These symbionts have the potential to alter invasion dynamics, and amphipod invasions provide an opportunity to explore such mechanisms. The link between host behaviour and parasitism is explored in the context of invasion by Bojko et al. (2018) and Bunke et al. (2019). These studies experimentally assess the effects of multiple microparasites on the activity, mortality

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and cannibalistic tendencies of invasive amphipod hosts. Their research reveals that infestation with parasites may affect whether an amphipod invader has high or low impact on an ecosystem, and that parasites may become more prevalent through altering their hosts cannibalistic tendencies in invasive populations.

Amphipods can be used as models to understand economically and environmentally relevant diseases from a systematic perspective. Discovery of such diseases in potential models is vital, especially for understudied diseases of which little ecological or environmental knowledge is available. Urrutia et al. (2019) provide a detailed study on Haplosporidia in amphipods, among other hosts, and explore how host infections affect other aquatic organisms within the same ecosystem. Phylogenetic analyses revealed that amphipod-infecting Haplosporidia are also found in multiple other hosts. These hosts may allow this parasite group to spread throughout the aquatic environment and even infect downstream farmed species.

Biological data related to parasitology are often confounded by the parasite's taxonomy, but host cryptic diversity can also be a factor for potentially unreliable data collection and interpretation. Galipaud et al. (2019) explore cryptic diversity in amphipods that host acanthocephalans, which are important parasites of vertebrates and undergo a complex life-cycle involving the Amphipoda. Their results indicate that host cryptic diversity in model systems has the potential to confound data collection, if not accounted for. Therefore, cryptic diversity in a host amphipod model must be explored when collecting related data, such as mortality-associated and behaviour-associated data related to parasitism.

Finally, the natural presence of parasites in model systems has often been linked with a distortion of host behaviour or perhaps physiology in parasitological experiments. When host organisms commonly used in model systems are not screened for parasites prior to experimental use, the resulting data may be confounded. Grabner & Sures (2019) reviewed the potential for inherent parasitism to alter the tolerances and effects of ecotoxicological substances in amphipod models, and they describe how this could alter resulting data and environmental decision making.

To conclude, model systems using amphipods and their systematically diverse assemblage of symbionts (viruses to large Metazoa) are highly adaptable. Amphipods are small, often easy to house, and are present across multiple habitats and a diversity of ecological niches. With both a versatile choice of amphipod host and parasite, the development of novel, or adaption of existing, models provide a wide range of possibilities for biological research. Many of the contributions to this Special use new model systems or adapt existing models to provide novel and interesting data on the broad topic of aquatic ecology; their continued use and development will aid our understanding of parasitism, and general symbioses, with regard to biological and diagnostic subject areas.

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