Trends in
Parasitology

Forum

Bridging the gap: aquatic parasites in the One Health concept

Christian Selbach [1,*]
Kim N. Mouritsen [1]
Robert Poulin [2]
Bernd Sures [3] and
Nico J. Smit [4]

The One Health framework emphasizes the interconnectedness of humans, animals, and the environment but often remains focused on human health. Here we highlight how the evolutionary and ecological dynamics of aquatic parasites are crucial to our understanding of these connected health aspects, especially in the light of environmental changes.

Aquatic parasites in One Health

The One Health (OH) concept was formulated as an interdisciplinary approach to achieve optimal health for people, animals, and the environment via collaborative actions across health and environmental sciences. Even though OH approaches have been expanded beyond their initially narrow focus on human and veterinary health, the environment remains a largely neglected component of this framework and OH strategies are mostly discussed in response to individual public health emergencies rather than acknowledging the inextricable links between human, animal, and environmental health [1]. Despite the relevance of water as the basis of all life on Earth, research on aquatic ecosystems and, in particular, aquatic parasites, appears under-represented in the OH literature (making up less than 4% of the literature on OH; Figure 1). This is not justified for two reasons. Firstly, some parasites with aquatic life cycles represent important disease agents for humans and wildlife (e.g., *Schistosoma*, *Giardia, Fasciola*). Secondly, aquatic parasites fulfil crucial ecosystem roles in freshwater, marine and estuarine habitats, and therefore regulate the overall health of these systems. Moreover, many parasites with multihost life cycles transition between aquatic and terrestrial hosts, thereby linking biotic interactions between ecosystems. Here, we call for a stronger integration of the ecological role of aquatic parasites into the OH framework, beyond the current – still too limited – focus on zoonotic disease transmission of particular pathogens. In fact, we believe that a better understanding of the ecology of aquatic parasites within OH can help to bridge the obvious gap between research on environmental, wildlife, and human health.

Parasites drive evolutionary dynamics

Complex natural ecosystems, consisting of multiple species and the interactions among them, are the product of a long evolutionary history. At individual and species levels, hosts have developed adaptations to their coevolving parasites. Often, the expression of normal behavior or the development of a healthy immune system depends on parasite infections (e.g., [2]). In the absence of parasites, hosts can sometimes achieve suboptimal phenotypes. Parasitic infections can also modify the host's microbiome (e.g., [3]), disrupting coevolved relationships between hosts and their microbes with an impact on disease emergence. Diversity at any trophic level has coevolved with that of other levels. Thus, across unperturbed systems, parasite diversity correlates strongly with host diversity [4]. In aquatic systems, where parasite diversity is particularly high and parasite biomass accounts for a substantial portion of total biomass [5], deficits in parasite diversity relative to host diversity, or changes in host–parasite interaction, can represent acute symptoms that the system has shifted away from its evolutionary equilibrium. Therefore, monitoring parasite diversity is a potentially powerful tool to assess the status of an ecosystem or its return to a healthy state following a disturbance. Yet, parasite diversity is not even mentioned in existing frameworks to assess or monitor aquatic ecosystem health [6]. Parasites are integral components of coevolved natural ecosystems and their full incorporation into OH approaches is necessary to achieve a holistic understanding of what determines the health and functioning of aquatic environments.

Parasites regulate ecosystem health

Although often remaining unnoticed, parasites play critical roles in shaping and modulating free-living communities in ecosystems either through their direct impact on host survival or through trait-mediated effects where, for instance, the phenotype or behavior of an ecologically important keystone species is modified by parasites. In aquatic ecosystems, the presence of even a single species of parasite can, under certain environmental conditions, cause large and cascading changes to biodiversity and ecosystem function. For instance, mass-mortality of ecosystem-engineering intertidal crustaceans has been linked to transmission of trematodes accelerated by unusually warm weather conditions [7]. As a consequence, the physical composition and stability of the sea bed changed, with a cascading effect on the entire benthic community of plants and animals in the habitat. While the ecological impact of parasites that directly regulate the abundance of host populations is relatively clear, more cryptic trait-mediated processes can be equally important. This has been demonstrated in a cockle–trematode system in which parasite infections induce surfacing of the otherwise buried bivalves, increasing the abundance and diversity of the surrounding invertebrate fauna that benefit from the greater structural complexity

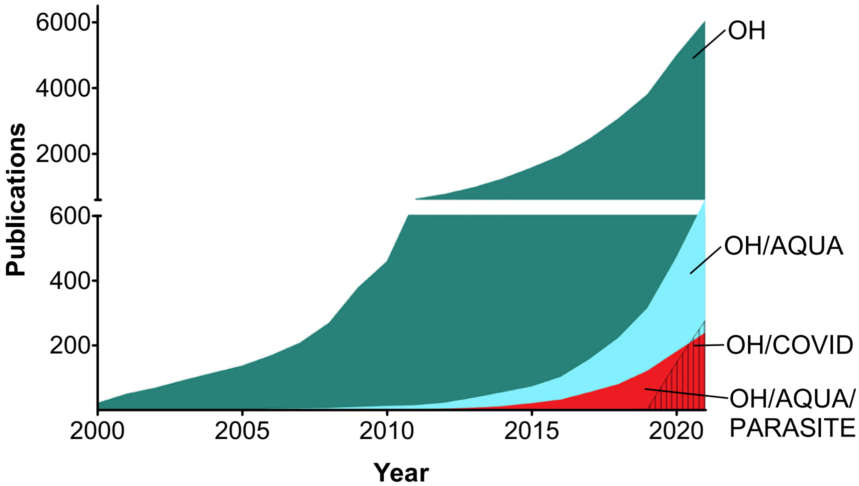

Figure 1. Cumulative publication output for research on One Health since 2000 (until September 2021). Of the 6023 articles retrieved for One Health (OH) only 10% (n = 616) focused on water and aquatic ecosystems (OH/AQUA) and less than 4% (n = 239) on parasites or pathogens (excluding viruses) in aquatic environments (OH/AQUA/PARASITE). For comparison, the recently emerging and fast-growing literature on Covid-19 (OH/COVID) makes up almost 5% (n = 277). Articles published between January 2000 and September 2021 were searched in the Web of Science, and the number of publications per year was retrieved from the database. Search terms: OH: 'one health'; OH/AQUA: 'one health' AND (aqua* OR water*); OH/AQUA/PARASITE: 'one health' AND (aqua* OR water*) AND (parasit* OR pathogen*) NOT virus*; OH/COVID: 'one health' AND (covid OR corona). Various other combinations of keywords (e.g., including 'disease') produced similar overall results.

at the sediment surface [8]. Likewise, recent findings have highlighted how the fear of parasitism can regulate and structure the ecosystem-engineering function of host species, for example, the nutrient cycling of bivalves in coastal habitats [9]. These examples highlight the central role of aquatic parasites in modulating and maintaining ecosystem health and function that must not be ignored in the OH assessment, especially since such community-structuring processes are often strongly reinforced at elevated temperatures due to greater parasite transmission rates.

Parasites in changing environments

Parasites are highly sensitive to environmental changes, sometimes with far-reaching ecological impacts. In particular, global climate change constitutes the largest threat and has a direct impact on parasites and their hosts, especially in aquatic environments where warming waters are known to speed up life cycles, extend parasite distribution ranges, and increase pathogenicity [10]. Moreover, global connectivity, movement of people and commodities, and species translocations across environmental boundaries have resulted in the spread of thousands of organisms beyond their native ranges. The majority of these invaders brought at least some of their parasites to new environments. When these cointroduced parasites are hardy, non-host-specific generalists they can flourish in new habitats and spill over to novel hosts that have no coevolutionary history and limited immunological defenses against them. Alternatively, if invasive hosts arrive without their parasites, they can outcompete and displace endemic free-living taxa, or dilute and remove native parasites from ecosystems (see [11]). These dynamic processes of host–parasite invasions can impact and modify the biodiversity and function of ecosystems and have potential environmental, human, and animal health consequences. Yet research on parasitism in the context of biological invasions remains largely under-represented in studies of invasion biology [11]. The Covid-19 pandemic has drastically brought to light how even individual spillover events can have considerable impacts in a globally connected world. Often unnoticed, parasite spillovers, spillbacks, or dilutions are constantly taking place in aquatic ecosystems around the world, and it is imperative that we study the effects of global change on aquatic parasites from an OH perspective in order to fully understand their impacts, and even more importantly, to find novel ways to mitigate these impacts within the context of global change.

Environmental parasitology

In addition to climate change and biological invasions that represent severe threats to ecosystem, animal, and human health, the increasing levels of pollutants from industrial, urban, or agricultural runoffs have major health impacts in aquatic environments. Here too, parasites play crucial roles and have recently been used as bioindicators to assess overall environmental conditions [12]. Moreover, several groups of intestinal helminths are able to bioconcentrate enormous amounts of toxic substances in their tissues, which qualifies them as sentinels for certain pollutants. A concomitant effect of the pollutant uptake capacity of many parasites is a significant reduction in contaminant levels in infected hosts compared to uninfected conspecifics (reviewed in [12]). Such a reduction in contaminant levels raises the question of whether parasites can even be beneficial to their hosts when the latter are exposed to contaminants (e.g., [13]). Although a huge amount of literature has focused on interacting negative effects of parasites and pollutants on host health, there is also convincing evidence that parasites associated with environmental contamination or changing environmental conditions can have beneficial effects on their hosts and make them more resilient

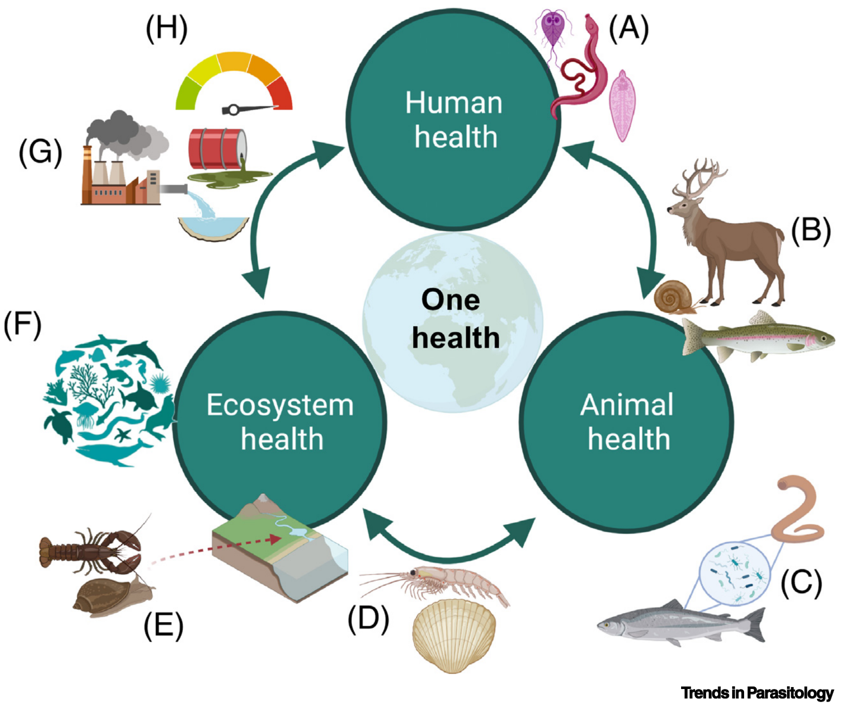

Figure 2. Key components of the One Health triad and central impacts of aquatic parasites in these contexts. (A) Water-borne and water-associated parasites as human pathogens, (B) parasites as pathogens of wildlife and domestic animals, (C) parasites regulating their host's microbiome and immune systems, (D) parasites affecting keystone species and ecosystem engineers, (E) host-parasite dynamics in invasion biology, (F) parasites as drivers of evolutionary processes and as major components of biodiversity, (G) interactions of parasites with pollutants in the environment, (H) parasites as bioindicators of ecological status and potential risks (see text for references). Figure created with BioRender.

to environmental stressors (e.g., [14]). These examples point to a so far largely neglected aspect, that is, that parasites themselves are not only part of the OH concept as pathogens but they might even play a substantial role in protecting free-living (host) organisms under specific circumstances, which needs to be addressed in future studies.

Concluding remarks: a call for integration

Undoubtedly, parasites are important pathogens of humans and wildlife. While there have been calls for stronger inclusions of parasitology into the OH framework, such initiatives have largely focused on the medical and veterinary relevance of parasites (e.g., [15]). However, here we highlight that aquatic parasites are also important drivers of central evolutionary and ecological dynamics that shape, control, and regulate the health and function of ecosystems (Figure 2). We therefore call for a reciprocal integration of parasitology and OH. We encourage parasitologists to highlight the ecological relevance of aquatic parasites within the OH framework, beyond their obvious role as disease agents. Likewise, we call for One Health initiatives to more explicitly incorporate the environmental roles of parasites, and for OH to expand its scope to encompass all of Earth's environments. This way, parasitology, and in particular aquatic parasites, can serve as a link between health and environmental sciences and contribute towards achieving the OH aim of interdisciplinary and holistic approaches.

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Declaration of interests

The authors declare no competing interests.

[1]Department of Biology, Aquatic Biology, Aarhus University, Aarhus, Denmark
[2]Department of Zoology, University of Otago, Dunedin, New Zealand
[3]Aquatic Ecology and Centre for Water and Environmental Research, University of Duisburg-Essen, Essen, Germany
[4]Water Research Group, Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

*Correspondence:
christian.selbach@bio.au.dk (C. Selbach).

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