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Editorial

Invasion ecology meets parasitology: Advances and challenges

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A B S T R A C T

Biological invasions threaten the diversity and functioning of native ecosystems, and the rate at which species are being introduced to new areas shows no sign of slowing down. Parasites play roles in biological invasions, for instance when native parasites interact with exotic hosts, or when parasites themselves are introduced to new areas. However, publication trends show clearly that research on parasitism in the context of biological invasions is lagging far behind research on biological invasions in general. The different articles in this special issue of *International Journal for Parasitology—Parasites and Wildlife* on 'Invasions' address various aspects of the interface between parasitology and invasion biology, including how invasive free-living species lose or gain parasites on the invasion front as they move away from their site of introduction, how these invasive species affect the dynamics of native parasites, and how exotic parasites become established and impact native hosts. Together, they highlight the challenges facing researchers in this area, and set the agenda for the next few years of research.

1. Introduction

Biological invasions, i.e. the establishment of non-native species outside of their natural range, represent a major threat to the diversity, integrity and functioning of ecosystems (Grosholz, 2002; Perrings et al., 2005; Molnar et al., 2008). They consist of the large-scale redistribution of species across the Earth, mostly as a consequence of human activities, and without the time necessary for gradual evolutionary adjustments of the native fauna and flora. For example, the intensification and globalisation of transport by ships has created repeated opportunities for the rapid introduction of small founder populations of aquatic alien species to new areas via ballast water (Cohen and Carlton, 1998; Ruiz et al., 2000; Drake and Lodge, 2004). Despite growing efforts to reduce invasion risk along multiple routes of introduction, recent estimates indicate that the rate at which alien species are detected shows no sign of slowing down (Seebens et al., 2017).

Biological invasions can implicate parasites in many ways. Free-living alien species may (i) succeed in a new area because they have been introduced without their parasites, (ii) be introduced along with their parasites with the latter then infecting native species, (i) or acquire native parasites following their introduction, leading either to the dilution or amplification of infection risk for native species (Prenter et al., 2004; Taraschewski, 2006; Dunn, 2009; Kelly et al., 2009; Poulin et al., 2011). Parasites may also be introduced to new areas without their original hosts, wreaking havoc on native hosts with no coevolutionary history with, and therefore no defenses against, these novel parasites (Prenter et al., 2004; Taraschewski, 2006; Dunn, 2009). This special issue of *International Journal for Parasitology—Parasites and Wildlife* on 'Invasions' is focused on the interface between parasitology and invasion biology. Its 8 contributions address various aspects of the role of parasites in biological invasions, either as lead actors or as influential factors. Before introducing the different contributions to this special issue, let's set the stage with a brief look at the history of research in this area.

2. The growing interest in parasites and invasions

Research on the impacts and control of invasive species has exploded in recent years. Has research on parasitism in the context of biological invasions been keeping up with research on biological invasions in general? To answer this question, a 'topic' search of the Web of Science® was performed for the period 1980 to 2016, using the following search string:

(introduc* or invasi* or exotic or "non-native") and (biodiversity or ecolog* or ecosyst*)

This yielded a total of 35706 records. Although these could not all be scanned individually to determine if they were relevant, a random inspection of about 300 records indicate that over 90% represent articles genuinely pertaining to biological invasions by plants or animals. Then, a second 'topic' search was conducted, covering the same period (1980–2016), but restricted to publications addressing either introduced parasites, the occurrence or absence of parasites on exotic hosts, the interaction of exotic hosts with native parasites, or some related phenomenon. The search was

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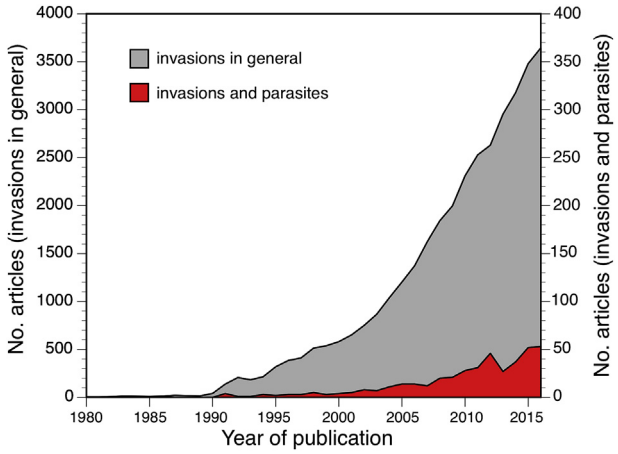

Fig. 1. Number of articles published per year, between 1980 and 2016, on either biological invasions in general, or more specifically on parasitism in the context of biological invasions, from a search of the Web of Science® (see text). Note the different scales on the y-axes for the two article counts.

limited to animal hosts and their metazoan parasites, specifically either trematodes, monogeneans, cestodes, nematodes, acanthocephalans, arachnids (ticks, mites), insects (lice, fleas) or crustaceans (copepods, isopods, branchiurans, rhizocephalans). The following search string was used:

(introduc* or invasi* or exotic or "non-native") and (biodiversity or ecolog* or ecosyst*) and (parasite* or helminth* or digene* or trematod* or monogene* or cestod* or tapeworm* or nematode* or roundworm or acanthocephal* or tick* or acari* or mite* or louse* or lice* or flea* or siphonaptera* or crustacean* or copepod* or isopod* or rhizocephal* or branchiura*)

All 2604 records retrieved were inspected individually to exclude irrelevant publications. The 417 records retained included a mixture of review articles, theoretical and empirical studies, addressing marine, freshwater or terrestrial systems or more general aspects that are not habitat-specific. As methods to detect and identify invasive parasites improve, we should be detecting more and more non-native parasites. However, fewer than 15% of the 417 relevant studies focus on introduced parasites; the vast majority investigate parasitism in exotic hosts, or the interactions between exotic hosts and native parasites.

What the results of these searches demonstrate is that research on parasitism in the context of biological invasions is not keeping up with research on biological invasions in general (Fig. 1). Not surprisingly, research on parasites represents only a small fraction of all research conducted on biological invasions (note the vastly different scales in Fig. 1). We are approaching 4000 articles per year on biological invasions, but only about 50 per year on parasitism in the context of invasions. Of greater concern, the rise in the number of research articles on the links between parasitism and invasion has been slow and erratic compared to the steady and accelerating rate at which general research on invasions is published (contrast the rising curves in Fig. 1). There is therefore both a need and an opportunity for parasitologists to contribute to knowledge on invasions that could mitigate their negative effects on native ecosystems.

3. This special issue on 'Invasions'

The contributions in this special issue address some of the knowledge gaps arising from the contrasting publication trends seen in Fig. 1. Firstly, they show that as they spread from their point of introduction, invasive free-living species gradually lose their original parasites. Perkins et al. (2017) report that infection levels by several parasites of the bank vole, *Myodes glareolus*, decline with increasing distance from the original area of introduction in Ireland, and Selechnik et al. (2017) report a similar pattern for lungworm infections in cane toads, *Rhinella marina*, spreading through Australia. Therefore, enemy release (see Colautti et al., 2004) may not always immediately facilitate the establishment of alien species, but may develop gradually along the invasion front. Interactions among the invader's parasites may also change along the way (Perkins et al., 2017), and native parasites may be acquired by the invader as it spreads (Selechnik et al., 2017), creating a dynamic scenario of host-parasite antagonism.

Second, the contributions in this issue explore the often neglected impact of invasive free-living species on the dynamics of native parasites. Lagrue (2017) reviews the many ways in which invasive crustaceans can alter the transmission success of native parasites, or the infection risk faced by native hosts, in freshwater ecosystems. These issues are explored using field data by Galipaud et al. (2017), who studied native and invasive amphipods of the genus *Gammarus*, living in sympatry and sharing acanthocephalan parasites in French rivers. Finally, Gendron and Marcogliese (2017) investigate how the invasive round goby, *Neogobius melanostomus*, may act to dilute the risk of infection by eyeflukes, *Diplostomum* spp., in native fishes of the St. Lawrence River, in Canada. These studies capture the various ways in which native parasites are influenced by invasive hosts, and in turn modulate the relative success of those invaders.

Third, addressing the lack of information on invasive parasites compared to invasive free-living species, Smit et al. (2017) provide an up-to-date list of non-native parasites recorded on South African freshwater fishes, one of the very rare such regional compilations. Then, Truter et al. (2017) report that largemouth bass, *Micropterus salmoides*, introduced to South Africa from North America, has left behind its endohelminths but co-introduced several monogenean species, adding to the list of invasive parasites in South African freshwaters. This sort of finding is worrying, because possible host-switches to native host species can have serious consequences. This is well illustrated by Welicky et al. (2017), who report that the invasive parasitic copepod *Lernaea cyprinacea* is capable of infecting native African fish, and causes a reduction in some measures of health and condition in the Mozambique tilapia (*Oreochromis mossambicus*).

Overall, the several contributions in this special issue address various facets of the interface between parasitology and invasion biology, as well as setting the agenda for the next few years of research. They highlight some of the challenges facing researchers in this area, such as the need to sample across large geographical scales, and to detect and accurately identify parasites and determine their origins. Yet they also point to important questions left unanswered, and offer ways to tackle them.

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