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Parasite prevalence in an intermediate snail host is subject to multiple anthropogenic stressors in a New Zealand river system

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ABSTRACT

Most ecosystems are exposed to multiple stressors acting in concert and their combined effects on parasite prevalence in freshwater, marine and terrestrial habitats are largely unknown. We investigated the relationships between farming intensity, water abstraction intensity and parasite prevalence in the mud snail *Potamopyrgus antipodarum* from 20 stream sites within the Manuherikia River catchment (New Zealand) by using generalized linear models and an information-theoretic model-selection approach. Three trematode taxa that use water birds as definitive hosts were found in the snail host. The average prevalence of all parasites infecting *Potamopyrgus* in the catchment was 5%. *Microphallus* sp. "lively", the most common parasite, was most prevalent at high farming intensity and low water abstraction, besides showing an antagonistic interaction between the two agricultural stressors. These findings highlight the importance of considering multiple stressors and their potential interactions when studying host–parasite systems. Because snails often play key roles in aquatic communities, providing an important link between primary producers and higher trophic levels, and are a common intermediate host to a high diversity of trematode parasites, this host–parasite model system may represent a promising bioassessment tool for detecting anthropogenic disturbances in freshwater systems.

1. Introduction

Global change, such as agricultural intensification and climate change, will have profound consequences for interspecific interactions in terrestrial, marine and freshwater ecosystems (Harley et al., 2006; Ficke et al., 2007; Tylianakis et al., 2008). The interactions among parasites, their hosts and their environment can reflect the impacts of environmental change on complex life-history strategies. The life cycles of parasites commonly include both free-living life stages and hosts at several trophic levels (Dobson et al., 2008), and parasites therefore contribute to a large number of links within food webs (e.g. Lafferty et al., 2008; Amundsen et al., 2013). Because their life cycles are closely linked to co-evolved predator–prey relationships, parasites can reflect both the stability and diversity of an ecosystem and may be an indicator of ecosystem health (Marcogliese and Cone, 1997; Marcogliese, 2005).

Anthropogenic activities such as agricultural land use and water abstraction are well-known drivers of freshwater ecosystems (Dudgeon et al., 2006). Both are important landscape-scale stressors, i.e. variables that exceed their range of normal variation due to human activities and affect ecosystem structure and functioning (Townsend et al., 2008). Such stressors can act on all life stages of parasites including egg and free-living larval stages, the fitness and density of potential hosts and their transmission processes (Pietrock and Marcogliese, 2003; Sures, 2004; Blanar et al., 2009).

In streams and rivers, agricultural land use can change many variables including increased primary and secondary production, habitat homogeneity, chemical contamination and water

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temperature (Allan, 2004). These changes are expected to alter prevalence of freshwater parasites through a number of mechanisms. For example, higher host density due to increased productivity should increase transmission success (Johnson et al., 2007). Conversely, transmission success may be impaired due to the vulnerability of free-living parasite stages, which are particularly sensitive to changes in water temperature and chemistry (Pietrock and Marcogliese, 2003). Pollutants have also been shown to reduce parasite production and emergence from snail hosts (e.g. Koprivnikar and Walker, 2011). However, exposure to glyphosate, a common agricultural herbicide, can experimentally increase trematode production and survival from *Potamopyrgus* snails (Hock and Poulin, 2012), underscoring the difficulty of predicting parasite responses to environmental stress.

Moreover, water abstraction for irrigation can reduce stream flows, and change temperature and sediment regimes (Dewson et al., 2007). These changes can then affect intermediate host abundance, transmission rates and biotic interactions in general (Poff et al., 1997; Bunn and Arthington, 2002; Thieltges et al., 2008). The effect of streamflow reduction on host–parasite relationships still remains unstudied.

Ecologists are becoming increasingly aware that multiple stressors can interact to form synergisms or antagonisms whereby the combined effects can be larger or smaller than expected based on individual stressor effects and so lead to "ecological surprises" (Christensen et al., 2006). However, to date few studies have investigated effects of multiple stressors on parasitism (but see Lenihan et al., 1999; Coors et al., 2008; Studer and Poulin, 2013), and none of these were conducted in running waters. This may be due to the challenges posed by the unidirectional flow, longitudinal gradients and frequent flood disturbances, which can all reduce parasite prevalence and make it difficult to detect parasites (Blasco-Costa et al., 2013). To the best of our knowledge, this is the first study assessing the effects of multiple stressors on parasite prevalence in streams.

Our host–parasite model system is the freshwater snail *Potamopyrgus antipodarum*, which is native to New Zealand and serves as the first intermediate host for at least 20 trematode species (Hechinger, 2012). Digenean trematodes (phylum Platyhelminthes) are a subclass of flatworms which require a molluscan first intermediate host and a vertebrate definitive host (e.g., fishes, birds) to complete its life cycle. They are a common and abundant component of freshwater communities (Morley, 2012). We aimed to study single-stressor and combined stressor effects of wide gradients of farming intensity and water abstraction intensity on parasite infection patterns at the catchment scale in multiple streams. We expected farming intensity and water abstraction to alter stream parasite prevalence because a previous study in the same catchment found strong effects of these two stressors on stream invertebrate communities (Lange et al., 2014a).

We tested two specific predictions. First, we hypothesized that parasite prevalence will show a positive relationship to farming intensity, due to a higher abundance of intermediate snail hosts as a consequence of nutrient enrichment. Secondly, we predicted parasite prevalence to show a negative relationship with water abstraction, as a consequence of a reduction of available habitats for free-living parasite life stages and intermediate hosts, and increased probability of disturbance (stream drying).

Our final objective was to look for potential non-additive multiple stressor patterns where the relationship along one stressor gradient depends on the intensity of the second stressor, forming interactive effects on parasite prevalence. Because no previous studies have investigated combined stressor effects on a landscape-scale, we had no specific hypothesis regarding the shape of these interactions.

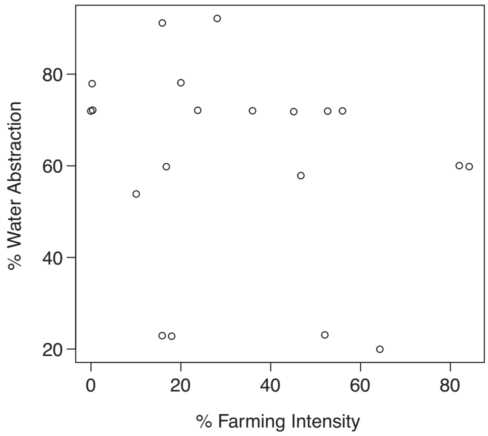

Fig. 1. Distribution of the 20 stream sites along the gradients of Farming Intensity and Water Abstraction.

2. Methods

2.1. Study sites

The study was conducted in the Manuherikia River catchment, which is located in the Central Otago region of the South Island of New Zealand. The river drains an area of around 3085 km^2 and is approximately 85 km long. The catchment is surrounded by mountains that provide shelter from most rainfall events, causing a semi-arid climate (Kienzle and Schmidt, 2008). Since the arrival of European settlers in the 1850s, large areas of the catchment have been converted from tussock grassland to managed pastures (Kienzle and Schmidt, 2008; Lange et al., 2014a,b).

Information on farming intensity in the Manuherikia River catchment was acquired from the spatial distribution of land cover types extracted from the New Zealand Land Cover Database (LCDB2, Ministry for the Environment, 2010). The catchment is dominated by tussock grassland (44%), low producing grassland (24%) and intensively managed high-producing exotic grassland (25%) (Lange et al., 2014b). The grassland is mainly used for sheep and beef farming. Our index of Farming Intensity was calculated as the percentage of high-producing exotic grassland in the upstream catchment from each stream site (detailed catchment delineations available from the River Environmental Classification, REC, Ministry for the Environment, 2010) and Water Abstraction intensity as the percentage of streamflow reduction from the *Dryland Scenario* (no water abstracted for irrigation) to the *Current Scenario* based on modelled streamflows by Kienzle and Schmidt (2008). Their modelled data were used to create different water-use scenarios to estimate the water abstraction intensity for each stream site (for more details see Lange et al., 2014b). In our study, Farming Intensity ranged from 0 to 84% and Water Abstraction from 20 to 92%. Farming Intensity and Water Abstraction were virtually uncorrelated (Fig. 1, $R^2 = 0.05$) because water for irrigation was abstracted and transported throughout the catchment. All sites were situated at 3rd to 5th order streams and tributaries to the Manuherikia River.

2.2. Biological sampling and sample processing

In austral autumn, between 21 March and 4 April 2011, benthic invertebrates were sampled from 20 stream sites in the catchment using a 500-μm kick-net in pool habitats following standard methods for semi-quantitative collections after Stark et al. (2001). At each site, the streambed was disturbed at 10 locations for 30 s. Collected invertebrates were pooled and preserved in 70% ethanol. We included only pool habitats in this study because *Potamopyrgus*