*Ecology letters - LETTER format - Maximum of 5000 words and 6 figures, tables or text boxes*

**1 | INTRODUCTION**

**[PAR1]** Often neglected in ecological studies (Morley, 2012; Scholz & Choudhury, 2014), parasites are a key component of natural communities and Biodiversity-Ecosystem-Functioning (Dobson & Hudson, 1986; Frainer et al., 2018; Lafferty et al., 2008; Marcogliese, 2004; Minchella & Scott, 1991; Pascal et al., 2020; Poulin, 1999). They are inevitably vulnerable to global changes and have been use as indicator of ecosystem health in the past (REFs). Yet, their spatial distribution patterns are still misunderstood as general rules are hard to uncover (Poulin, 2007). One of the first steps to disentangle those context-dependencies is to address the importance of spatial scaling for the estimation of infection parameters in biotic communities (here prevalence of infections).

**[PAR2]** Infection patterns are variable across taxa, time and space (Happel, 2019; Poulin, 2006; Poulin & Dick, 2007; Thieltges & Reise, 2007; Villalba-Vasquez et al., 2018; Young & Maccoll, 2017). However, it remains unclear whether these patterns are the results of stochastic events or deterministic filtering as current literature on the subject lacks consistency (Carney & Dick, 2000; González & Poulin, 2005; C. R. Kennedy, 2009; Poulin, 2007; Poulin & Valtonen, 2002). In parasite ecology, scaling is of most importance because of hierarchical organization of host-parasite systems (see Bush et al., 1997 for organization levels definitions). In the search of uncovering processes shaping host-parasite dynamics, parasite ecologist must consider encounter and compatibility filters (Combes, 2001). Encounter filter refers to spatio-temporal window allowing encounter between a parasite and its host while compatibility filter refers to intrinsic properties of parasite-host association that determines success of infection (Combes, 2001). In the context of our study, we will focus on encounter filters as, in a management perspective, they are easier to measure in the field and less invasive on biodiversity. Studies have shown that both biotic and abiotic component can be correlated to variation of infection metrics at small and large scale (Altman & Byers, 2014; Falke & Preston, 2021; Lagrue et al., 2011; Lagrue & Poulin, 2015; Poulin & Morand, 1999; Thieltges et al., 2008). A complete ecological perspective on these systems must incorporate both abiotic and biotic drivers to highlight processes shaping patterns at multiple scales. That said, we lack crucial information on how patterns and predictors change across scale to properly monitor and managed parasites in freshwater ecosystems.

**[PAR3]** Here, we test the effect of spatial scale on infection prevalence estimates across different sampling methods using data on the black spot disease in littoral fish communities across X lakes varying in morphometric attributes and local conditions. We analyze infection prevalence data through three scale levels **(1)** Regional-scale – effect of random sampling on prevalence estimation, **(2)** Local-scale – distribution of observed prevalence measure, **(3)** Fine-scale – identify ecological predictors of prevalence infection. For regional scale estimates we used random prevalence accumulation curves by re-sampling across lakes. This approach allows us to compare regional-scale prevalence estimates (and associated variance) among different sampling methods along a gradient of increasing sampling effort (or area sampled). Akin to interpretations of species-area relationships, the accumulation curves can show evidence for scale-invariance (“flat curve”, infection prevalence does not change with increasing sampled area because it is well-mixed across samples) or for spatial aggregation (the number of infected individuals sampled vary non-linearly with the number of individual sampled). Patterns of regional-scale estimates from random sampling can be caused by different underlying local patterns of infections. For instance, a regional prevalence of 20% could be caused by all lakes being at 20% or by all lakes being at 20% on average (e.g., half at 0% and half at 40%). Thus, investigating local-scale patterns is important to bring the necessary nuances on the regional-scale estimates and to infer processes properly. The final step was to use a suit of deterministic environmental predictors at both local and regional scales to understand the observed infection prevalence and explore whether some indicators could be useful for management of parasite infections in fish communities at local and regional scales. Our goal here was not to make prediction on spatial distribution of the parasite but disentangle how infection patterns are shape through different scale to make monitoring of parasitic infection in freshwaters easier.

Old stuff.

[PAR2] Parasites can influence natural populations and communities in many ways. By definition, parasites must benefit from their host at their expense. Coûts indirects

**[Physiological]** These energetic demands trigger metabolic responses that may induce physiological impairments to the host. For example, (Rohlenová et al., 2011) showed that infection by cestodes stimulates immune response by activating phagocytes cells. Resources allocation is a trade-off between energetic demands of the host. Increasing immune response comes with a lesser energy budget for the other functions such as growth, reproduction and maintenance of vital organs. Parasite load may also induce stress that results in performance alteration such as swimming behavior and escape time (Allan et al., 2020). Other parasites migrate through tissues causing direct physiological damage. For example, eye flukes cause their host cataract that reduces visual acuity hampering predation escape and foraging behaviour (Seppälä et al., 2005; Vivas Muñoz et al., 2019).

Lafferty and Shaw, 2013

**[Behavior & Cognition]** Another way to escape infection is by avoiding infected conspecifics/mates or hot spots of infection (*i.e.* parasite avoidance behaviours)(see (Behringer et al., 2018). For example, [*habitat*] (Karvonen et al., 2004; Poulin & FitzGerald, 1989) [*conspecifics*] (Dugatkin et al., 1994; Ward et al., 2005) [*mates*](C. E. J. Kennedy et al., 1987; Milinski & Bakker, 1990; Rosenqvist & Johansson, 1995)

Parasite manipulation…

Mikheev et al., 2010

Rainbow trout (*Oncorhynchus mykiss)* infected by eye fluke *Diplostimum spathaceum*. Parasite infection increased aggressiveness but infected fish lost contests for a territory against control fish. Parasitized fish pay the cost of aggressiveness without the benefit of acquiring territory.

See Binning et al., 2017

Infection can alter host locomotor performance via impacts on host morphology and physiology.

Neglecting the role of micropredators on performance capacity and behaviour of their hosts can greatly affect our understanding of a species’s ecology.

Behavior manipulation

Predator avoidance but less neophobia to new foods in fish suggest complex modulation of risk-averse behaviour. (Freire et al , 2022)

Lafferty and Shaw, 2013

Infected vertebrate hosts had more strongly altered microhabitat choices than did invertebrate hosts

Host microhabitat choice or host activity

Two types of behaviour : increased contact with predator and/or decreased reaction to predators

Vertebrate hosts were more associated with decreased reations

Mechanims of host manipulation : energetic drain, site of infection, neurmodulation (hormonal and neuronal activity)

**[Dynamics & BEF]**

(Anderson et May, 1979; May et Anderson, 1979; Scott et Dobson, 1989)

Dispersion

Kuris et al., 2008. Total parasite biomass in estuarian system – Important component of matter and energy fluxes.

Anguilla eel species infected by nematode which dammande swim bladder, thus buoyancy and swimming performance (Palstra et al., 2007)

Development of abnormalities

Coral reef fishes infected with Anilocra isopod – less active during the day, smaller territoiriesm low water flow habitats (Meadows and Meadows, 2003; Welicky and Sikkel, 2015).

Mortality resulting directly from parasite infection aanlone can put host population viablility at risk, leading to local population extinction (Jensen & Jensen, 1992; Boots and Sasaki, 2002)

Deacreasing probability that migrating individuals successfully reach their breeding grounds (Moller et al., 2004; Palstra et al., 2007)

Infection can influence spatial distribution /spatial structure of population (Poulin, 1999; Curtis, 2002; Poulin and Latham, 2002; Miura et al 2006) – Increasing migratory connectivity (Mollet and Szep, 2001) – Increasing trophic connectivity of ecosystems (Welicky and Sikkel, 2015)