Top-down and bottom-up effects and relationships with local environmental factors in the water frog–helminth systems in Latvia

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INTRODUCTION

Top-down and bottom-up interactions in ecology refer to direct interactions between adjacent trophic levels, where parasites are placed higher but their hosts lower accordingly to the concept of biomass pyramid.

Amphibian helminths include monogenean, trematode, cestode, acanthocephalan, and nematomorph worms, which all are endomacroparasites characterized by relatively large size and lack of asexual replication in vertebrates; they often have complex life cycles with one or more intermediate hosts, and cause infection intensity-dependent pathologies.

MATERIALS AND METHODS

To study top-down and bottom-up effects, we conducted calling male water frog counts and parasitological investigations of helminths in waterbodies from different regions of Latvia, supplemented by descriptions of waterbody features and surrounding land use data.

We performed a series of generalized linear model and zero-inflated negative binomial regressions to determine the best predictors for frog relative population size and helminth infra-communities.

Figure 1. Location of study sites in Latvia; waterbodies that were sampled in 2018–2022 for the helminth infections in water frogs together with frog audible surveys (n = 63) denoted with the red pins. Maps were prepared in Google *Earth* v. 7.3 software using pin tool; attribution to the Google Earth seen in lower left corner; personalization of maps made accordingly to Google attribution guidelines published here: https://about.google/brand-resource-center/products-and-services/geo-guidelines/#required-attribution.

MAIN FINDINGS

- ✓ Top-down effects of parasites on water frog population size were markedly weaker than the effects from both waterbody characteristics and terrestrial habitats.
- ✓ In the model rankings by AICc, the most qualitative GLM model explaining water frog population size contained only the waterbody factor, and it was followed by the model containing land use within 500 m (L500) only. The model containing parasite factor was on the bottom of the ranking by AICc.
- ✓ Helminth infra-community species richness had a negative effect on the water frog population size; however, helminth abundances showed no significant impact on the water frog population size and the host-parasite systems in water frogs seems to be evolved towards low levels of virulence and commensalism
- ✓ The bottom-up effect from the host population size was observed only for larval diplostomid trematodes, which were more abundant in water frogs from larger populations, and this was an important factor with about the same rank as the most influential environmental factor (waterbody features).
- ✓ In abundances of adult plagiorchiids and nematodes the best predictor was the host specimen size. Environmental factors had both direct effects from the habitat features (e.g., waterbody characteristics on frogs and diplostomids) and indirect effects through parasite-host interactions (impacts of anthropogenic habitats on frogs and helminths).
- ✓ **Our study suggests the presence of synergy between top-down and bottom-up effects in the water frog–helminth system that creates a mutual dependence of frog and helminth population sizes and helps to balance helminth infections at a level that does not cause over-exploitation of the host resource.**

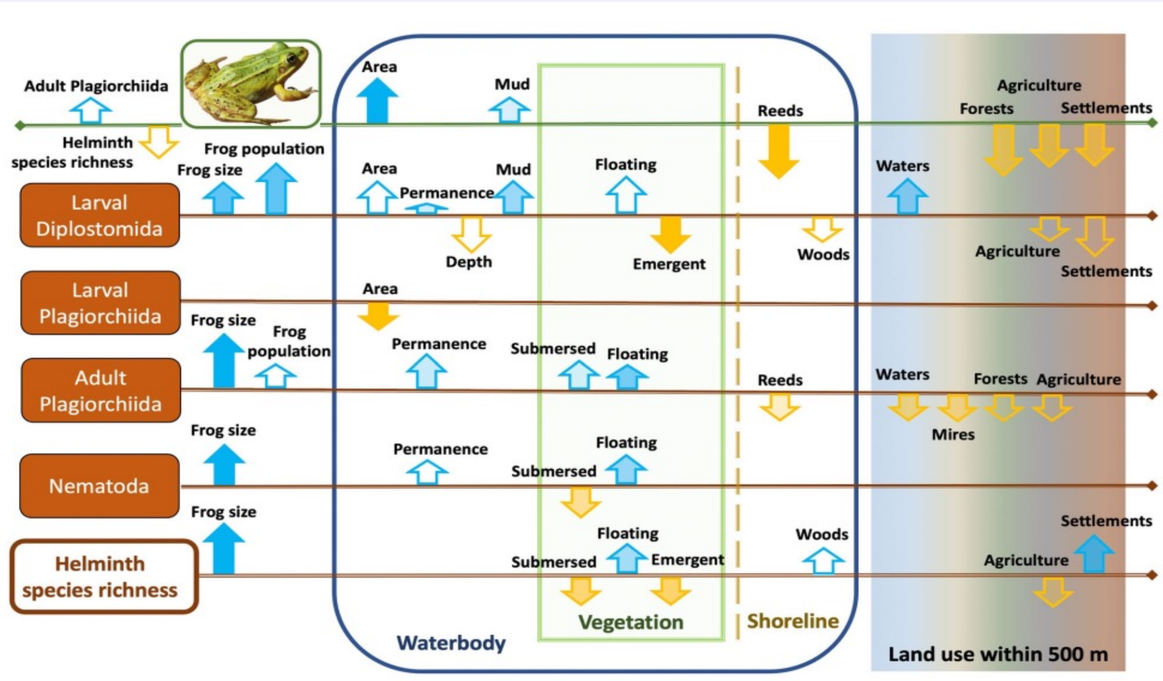

Figure 2. Ecological factors that affected water frog (*Pelophylax* sp.) population size (denoted with a picture of the water frog), abundances of their main helminth groups and their total helminth species richness in 63 waterbodies from Latvia, sampled in 2018–2022. Blue arrows indicate positive, orange arrows—negative relationships with a given factor in statistical models. Arrow heights are proportional to the average z-score in statistically significant models (generalized linear model regressions for the frog population size, and zero-inflated negative binomial regressions—for heminths), but the degree of their filling is proportional to the rank of the relative quality of their best model (Tables 2 and 3).

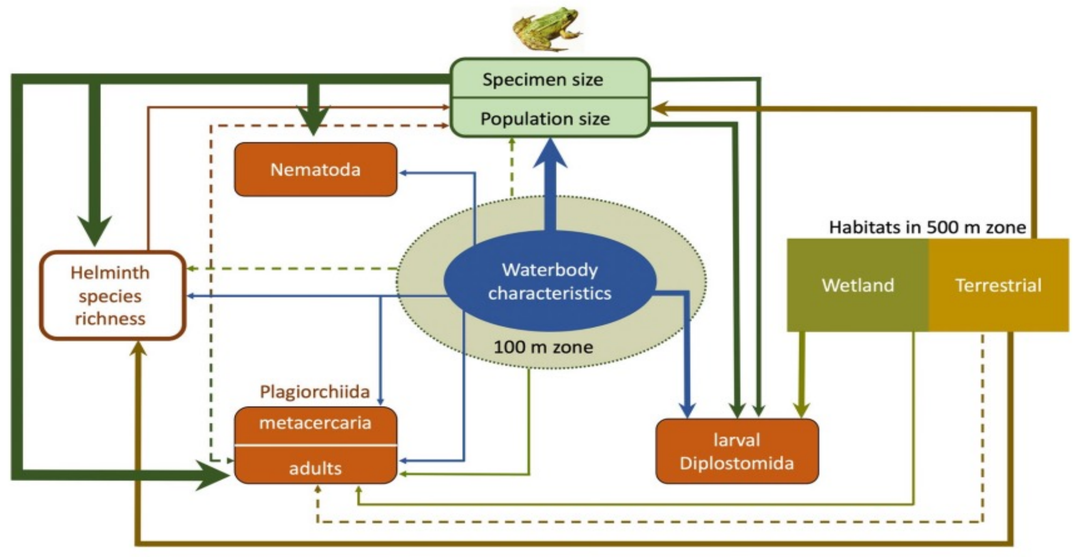

Figure 3. Flow chart showing relationships between the water frog-helminth-environment system components in our study. The thickness and continuity of arrow-headed lines is proportional to the strength of their suggested effects; helminth species richness refers to the infra-community richness (species richness in individual frog hosts), but different helminth groups refer to their abundances in hosts.

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