Exploring the Implication of Microplastic Consumption on Guppies

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NOTE

Microplastic exposure and consumption increases susceptibility to gyrodactylosis and host mortality for a freshwater fish

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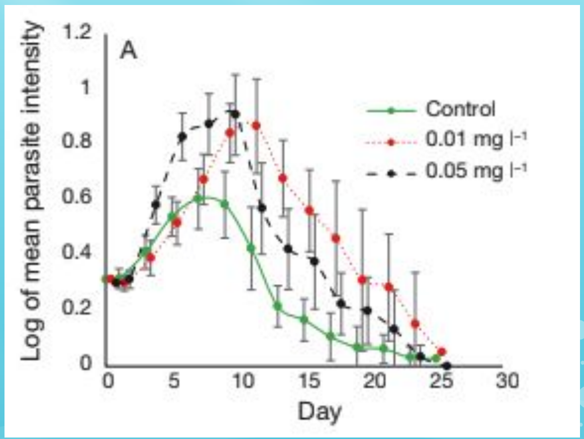
ABSTRACT: Microplastics have been found in all surveyed ecosystems and in the diet of multiple species. Detrimental health impacts of microplastic consumption include reduced growth and fecundity, metabolic stress and immune alterations for both invertebrates and vertebrates. Limited information exists, however, on how disease resistance may be affected by microplastic exposure and consumption. Here, the impact of microplastic (0.01 and 0.05 mg l^{-1} of polypropylene) on fish host susceptibility to disease and mortality was assessed using the guppy *Poecilia reticulata*–gyrodactylid *Gyrodactylus turnbulli* system. Fish exposed to and/or consuming microplastic at both concentrations demonstrated significantly higher pathogen burdens over time compared with fish fed a plastic-free diet. Furthermore, microplastic (at both tested concentrations) was associated with increased mortality events for fish within all treatments, regardless of host infection status. This study adds to the growing body of evidence showing that microplastic pollution can be detrimental to fish welfare by reducing disease resistance.

KEY WORDS: Microplastic · Host–parasite interactions · Disease resistance · Fish welfare

Research Question

- From the article *Microplastic exposure and consumption… (Masud & Cable*, 2023), what would be an appropriate system of ODEs and set of parameters to accurately simulate the experimental results in Figure 1 (a)?
- Goal: Explore the implicit relationship between the guppy immune system and the consumption of microplastics.



Background

- Microplastic concentrations in water are higher near the shore line than in open water.
- Various types of microplastics can enter the waterways through various anthropogenic activities.
  - “Plastic waste correlates with population density” (Kye, et al., 2023).

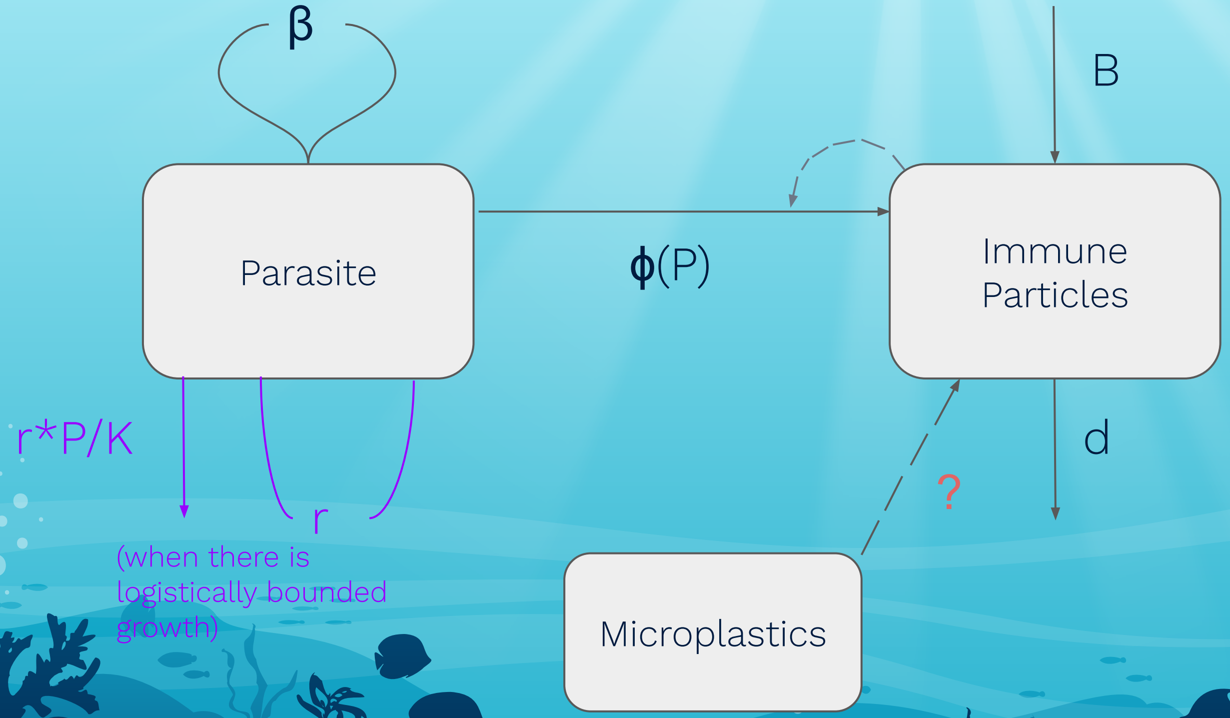
1.
Model Overview

Modeling assumptions, flow diagram, and modeling equations

Modeling Assumptions

- The guppies do not die during the experimental period.
- Immune particles act as the immune system of the guppies and directly fight off the parasites.
- There is an underlying background level of constant production of immune particles present at all times in the guppy.
- The guppies do not reproduce during the experimental period.
- The parasites can reproduce during the experimental period.
- Parasites do not experience natural death.

Flow Diagram



Parameters:

- β: [time^-1]
- B: [I.P. time^-1]
- d: [time^-1]
- r: [time^-1]
- K: [parasites]
- ϕ(P): Functional response
  - Rate at which the I.P. “captures” the parasites

Model Equations

Without bound on growth of the parasites:

$$\frac{dP}{dt} = \beta P - c\Phi(P)I$$

$$\frac{dI}{dt} = B - dI + f\Phi(P)I$$

With logistic bound on growth of parasites:

$$\frac{dP}{dt} = rP(1 - \frac{P}{K}) - c\Phi(P)I$$

$$\frac{dI}{dt} = B - dI + f\Phi(P)I$$

Functional Responses:

$$\Phi(P) = P \quad \Phi(P) = \frac{P}{a+P} \quad \Phi(P) = \frac{P^2}{a^2+P^2}$$

Parameters:

- c:
  - HT1: [1/ I.P. time^-1]
  - HT2&3: [parasites/ I.P. time^-1]
- f:
  - HT1: [1/P time^-1]
  - HT2&3: time^-1]
- a: [parasites]

2.
Results with R

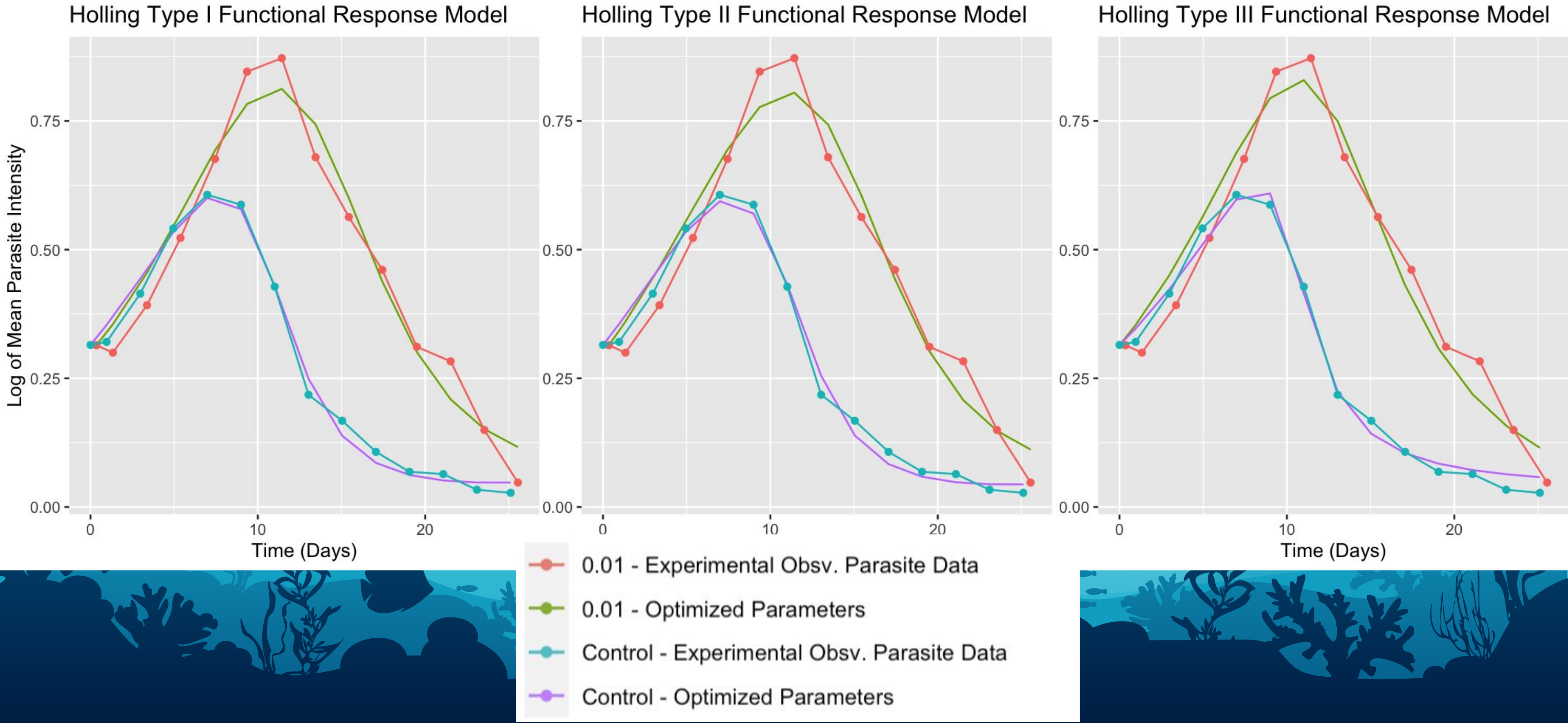
Simulation results from proposed model formulations

Analysis

We will be focusing on the “unbounded parasite growth” model.

- Simulate ode
- Optim for optimizing the parameters by fitting them to the data
- Comparing the RSS for HT II and HT III
- Comparing all models at optimized parameters via AIC

Plots of Simulated and Observed Data



Comparing Models

- The HT II and III models have the same number of parameters so we can compare them with their respective RSS (Galvao & Araujo, 2009) .

RSS	Holling's Type II	Holling's Type III
Control Data	0.01058965	0.002733347
0.01 mg/l Data	0.03805021	0.02844157

- The HT III model has the lowest RSS for both data sets, thus is the better of the two models by this metric.

Comparing AIC

AIC	Holling's Type I	Holling's Type II	Holling's Type III
Control Data	-58.90567	-54.45174	-56.41178
0.01 mg/l Data	-31.29976	-29.03474	-27.67159

The HT I model has the lowest AIC for both data sets, thus is the best of the three models.

Future Work

- Future Work:
  - Look further into biological aspects of the guppy immune system.
    - Initial conditions for “healthy” vs. “compromised” fish
  - Analytical investigation into the dynamics of the set of equations with logistic growth of the parasite.
  - Parameter estimation for the set of equations with logistic growth of the parasite.
  - Consideration of microplastics as a state variable to create an explicit relationship.

Reflection

- This project help me consider a different perspective of the interactions between species.
- This project helped me explore functional response parameter fitting in R.
  - This ties together concepts learned in previous math classes with topics from this class.

Citations

Masud, N., & Cable, J. (2023). Microplastic exposure and consumption increases susceptibility to gyrodactylosis and host mortality for a freshwater fish. *Diseases of Aquatic Organisms*, *153*, 81–85. https://doi.org/10.3354/dao03721

Kye, H., Kim, J., Ju, S., Lee, J., Lim, C., & Yoon, Y. (2023). Microplastics in water systems: A review of their impacts on the environment and their potential hazards. *Heliyon*, *9*(3). https://doi.org/10.1016/j.heliyon.2023.e14359

Kot, M. (2001). To cycle or not to cycle. In *Elements of mathematical ecology* (Vol. 1, pp. 116–139). essay, Cambridge University Press.

Galvao, R. K. H., & Araujo, M. C. U. (2009, February 10). *Variable selection*. Comprehensive Chemometrics. https://www.sciencedirect.com/science/article/abs/pii/B9780444527011000752

Esmaeili M. (2021). Blood Performance: A New Formula for Fish Growth and Health. *Biology*, *10*(12), 1236. https://doi.org/10.3390/biology10121236