Modeling Population Dynamics of Great Lakes Fish Exposed to PFOS

Introduction

Since production began in the 1940's, PFOS chemicals have been entering our environment. A study on PFOS exposure to zebrafish concluded that this exposure can lead to hepatic immunotoxicity (Huang, 2022). These chemicals have also been shown to bioaccumulate and were found to be 10-20 fold greater in predatory fish than their prey (Kannan, 2005).

Lake Trout

Lake Whitefish

Steelhead Trout

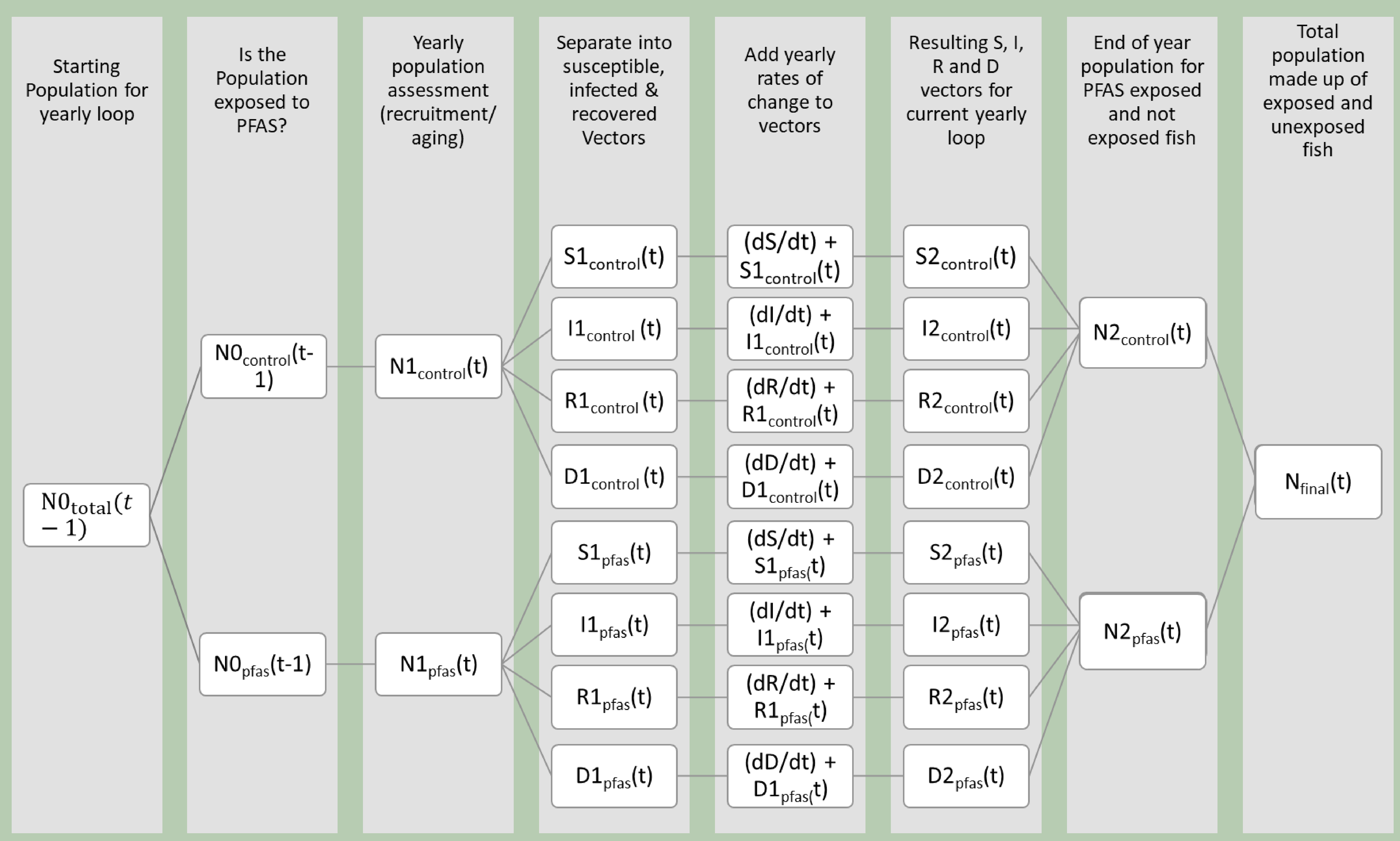
Problem Statement

My project is part of a larger project designed to understand the effects of PFOS contamination on the immune function of Steelhead Trout, Lake Trout and Lake Whitefish. I will be creating a population model with an age matrix structure that will simulate the population level impacts of PFOS contamination on these fisheries.

Methods

I created a compartmental SIR model with an age matrix structure (Fenichel, 2009; Mubayi, 2021). This model can be simulated over any timeframe to show future population impacts calculated using the specific set of parameters. Due to a lack of research about PFOS impacts on aquatic species, there are many assumptions in the model that may be modified as more information becomes avalible.

How does the model work?



Anticipated Results

This is the first model of this type and it can be used to simulate population level effects caused by PFOS contamination. This model will provide a framework for making management decisions about valuble fisheries in the Laurentian Great Lakes. As more research is done on this topic, the model can be improved to better simulate these population level changes.

Parameters

R_o = recovery rate from infection **

D_o = disease mortality rate **

D_n = natural mortality rate

D_f = fishing mortality rate

β = transmission rate of disease pathogen **

** may vary depending on exposure to PFOS

References

[1] Fenichel, E. P., Tsao, J. I., & Jones, M. L. (2009). Modeling Fish Health to inform research and management: renibacterium salmoninarum dynamics in Lake Michigan. Ecological Applications, 19(3), 747–760. https://doi.org/10.1890/08-0564.1

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[3] Kannan, K., Tao, L., Sinclair, E., Pastva, S. D., Jude, D. J., & Giesy, J. P. (2005). Perfluorinated compounds in aquatic organisms at various trophic levels in a Great Lakes Food Chain. Archives of Environmental Contamination and Toxicology, 48(4), 559–566. https://doi.org/10.1007/s00244-004-0133-x

[4] Mubayi, A., Pandey, A., Brasic, C., Mubayi, A., Ghosh, P., & Ghosh, A. (2021). Analytical estimation of data-motivated time-dependent disease transmission rate: An application to ebola and selected Public Health Problems. Tropical Medicine and Infectious Disease, 6(3), 141. https://doi.org/10.3390/tropicalmed6030141

Equations

$$\frac{dS}{dt} = -\beta \frac{S}{N} I - d_n S - d_f S$$

$$\frac{dI}{dt} = \beta \frac{S}{N} I - (r_0 + d_0 + d_n + d_f) I$$

$$\frac{dR}{dt} = r_0 I - d_n R - d_f R$$

$$\frac{dD}{dt} = d_0 I + d_n (S + I + R) + d_f (S + I + R)$$

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