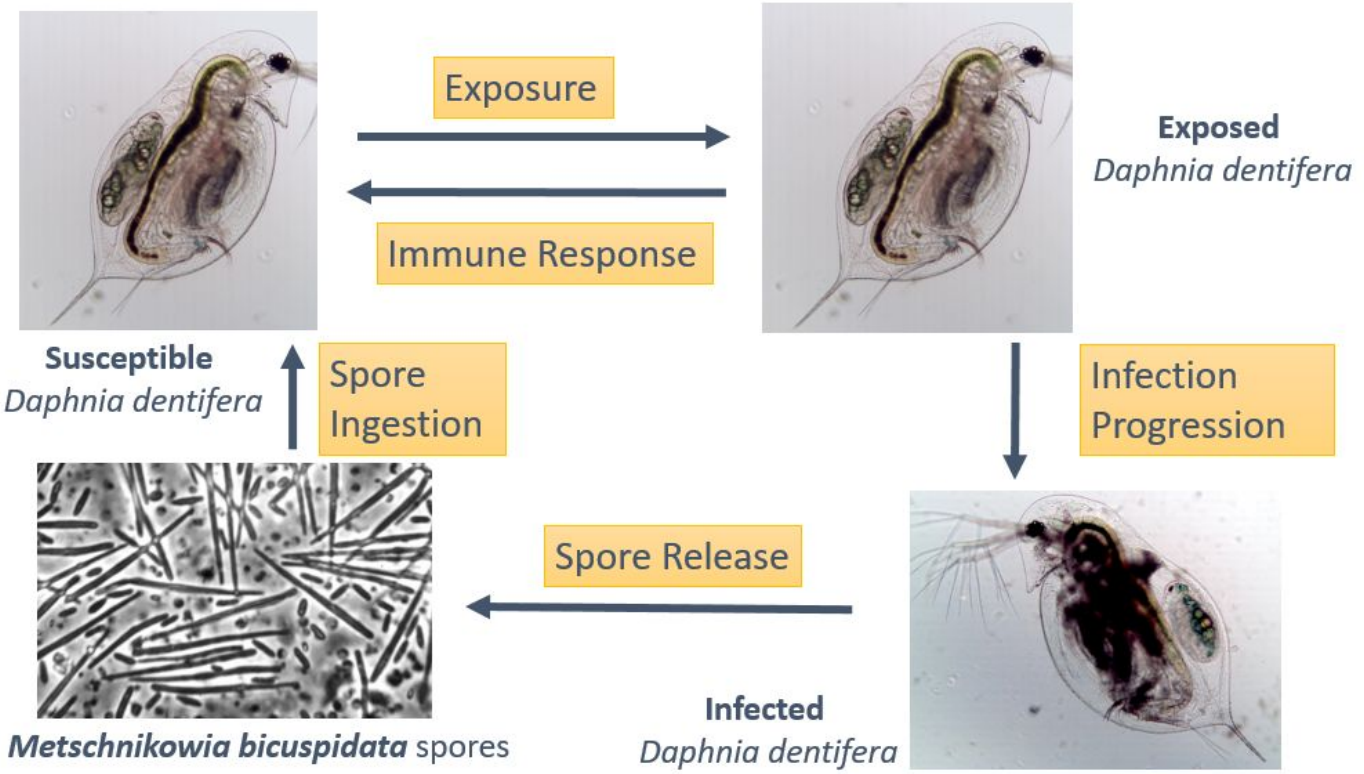
Sky of Blue, Sea of Green

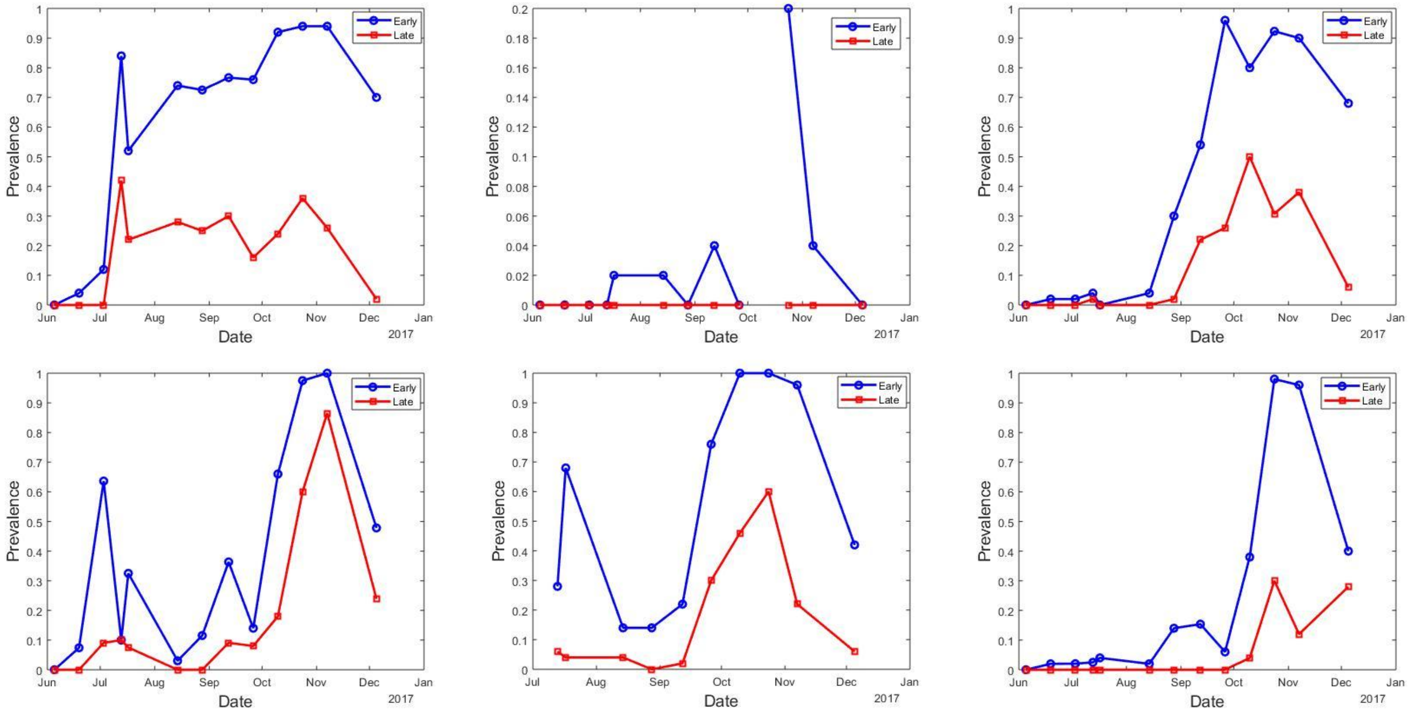
Exploring Environmental Factors and Host Resilience Response in Epidemic Dynamics

Dillon Max, Gabriel Kosmacher

Background


Exposure
Immune Response
Exposed
Daphnia dentifera
Susceptible
Daphnia dentifera
Spore Ingestion
Infection Progression
Spore Release
Metschnikowia bicuspidata spores
Infected
Daphnia dentifera

Field Data


Prevalence
Date
Early
Late
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
2017

Daphnia Dynamics Model

Host Growth (Logistic) | Death | Exposure | Immunity

$$\frac{dS}{dt} = B_t b(t)(S + \rho(E+I))\left(1 - \frac{S+E+I}{k_t K(t)}\right) - (d + P_t p(t))\,S - \beta S Z + k\Gamma_t \gamma(t) E$$

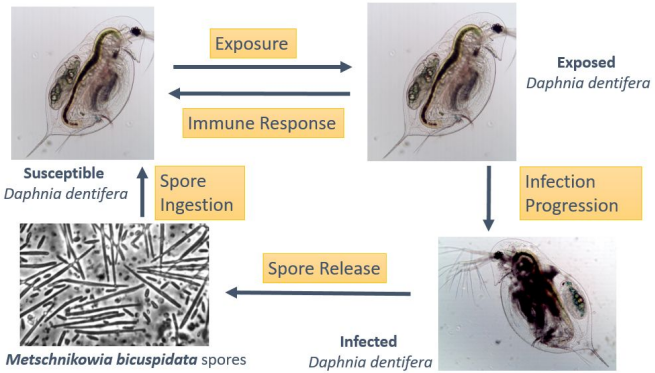
$$\frac{dE}{dt} = \beta S Z - [d + P_t p(t)]\,E - k\Gamma_t \gamma(t) E - (1-k)\alpha E$$

Progression

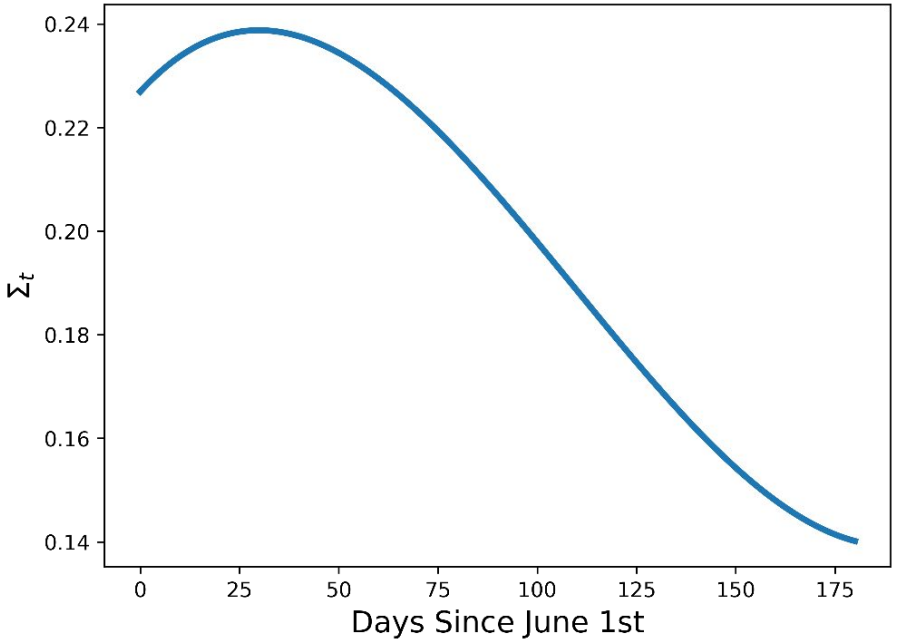
$$\frac{dI}{dt} = (1-k)\alpha E - [d + v + \theta P_t p(t)]\,I$$

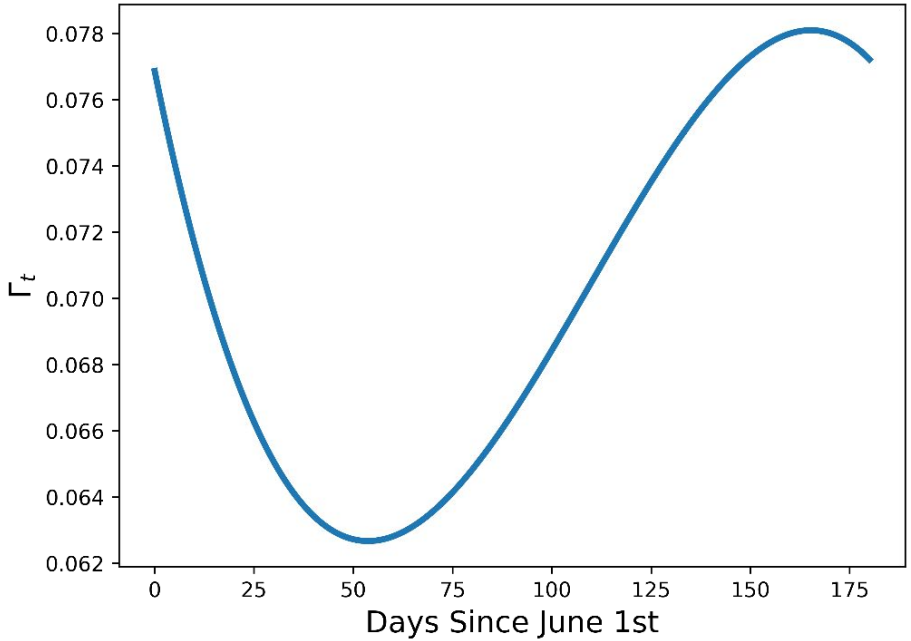
$$\frac{dZ}{dt} = \Sigma_t \sigma(t)\,[d+v]\,I - \lambda Z - f\,[S+E+I]\,Z$$

Release | Loss | Consumption

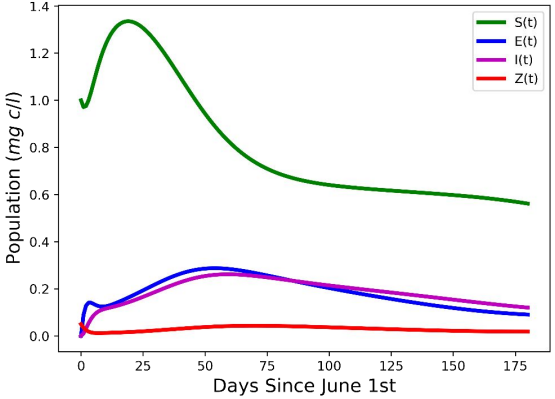


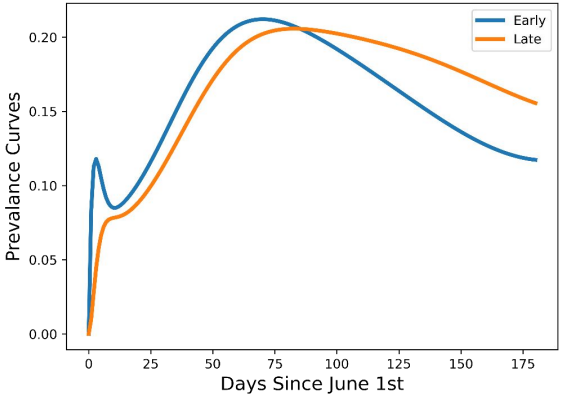
Seasonality Parameters



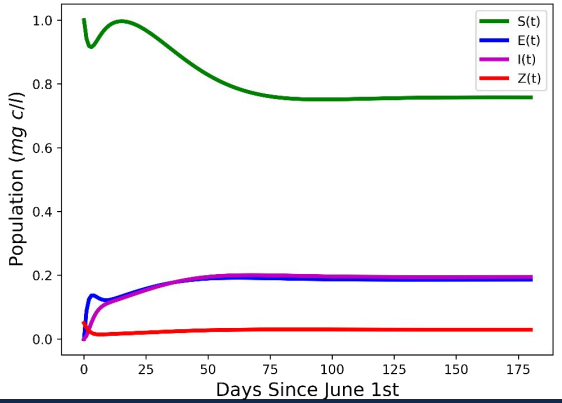


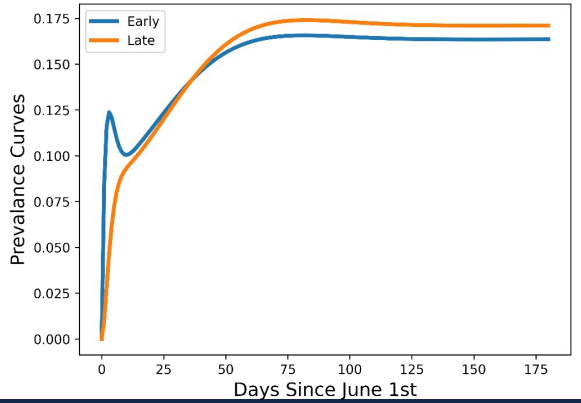
No Seasonality



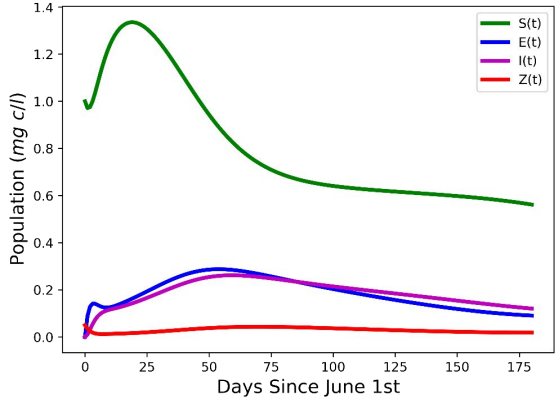


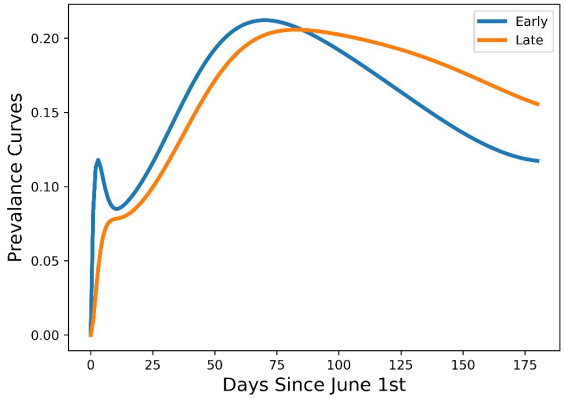
p = 0.55, k=0.1, sigma=0.35



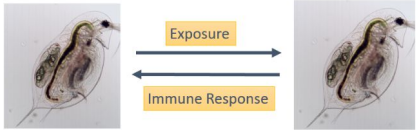


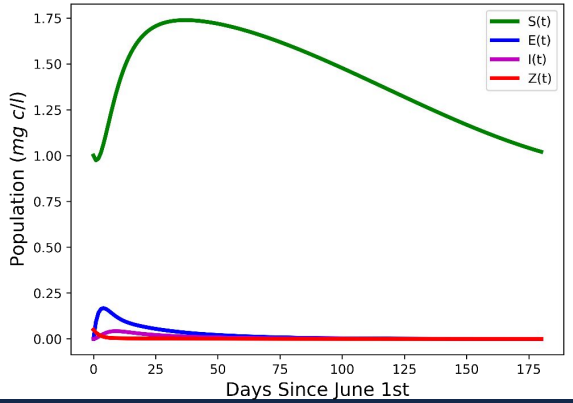
Too Much Recovery?

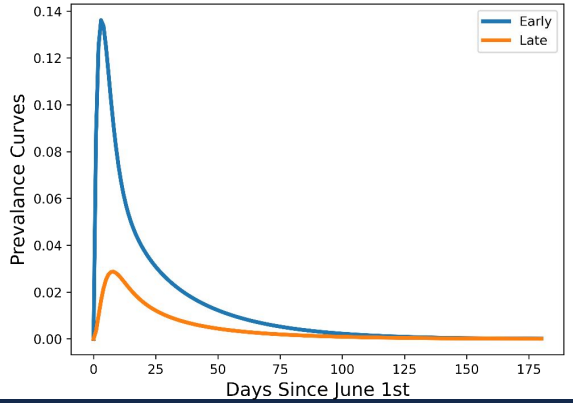




p = 0.55, k=0.1, sigma=0.35

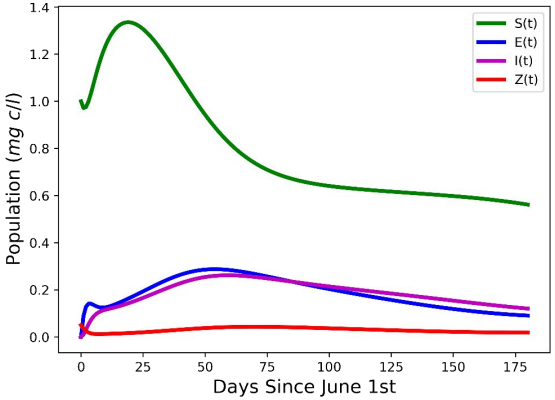


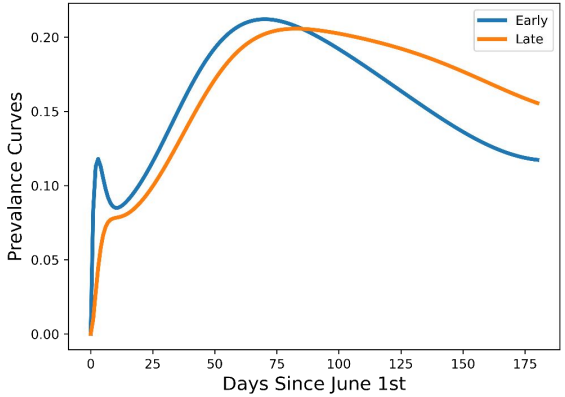




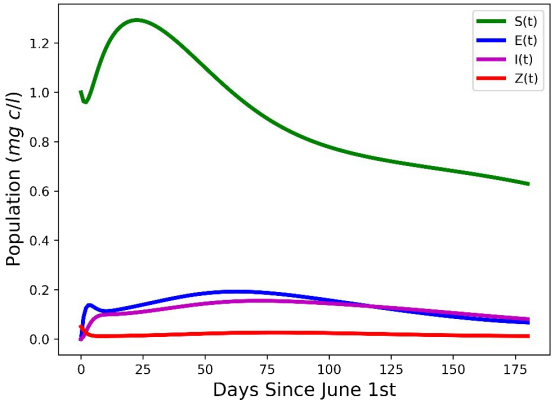
p = 0.55, k=0.7, sigma=0.35

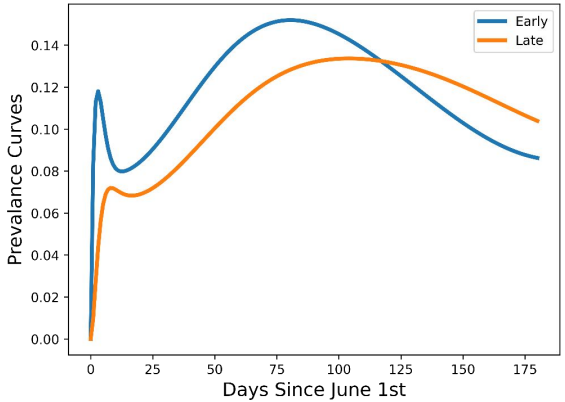
Impact of Fish Hunger?





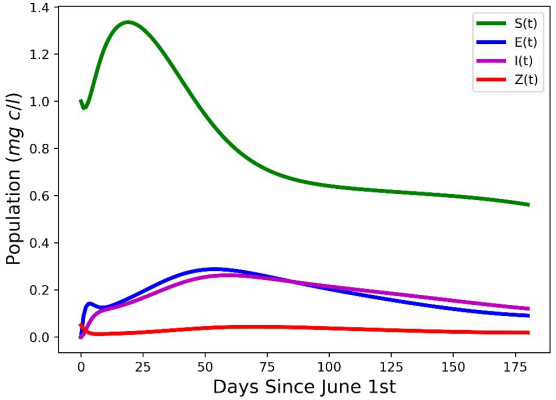
p = 0.55, k=0.1, sigma=0.35

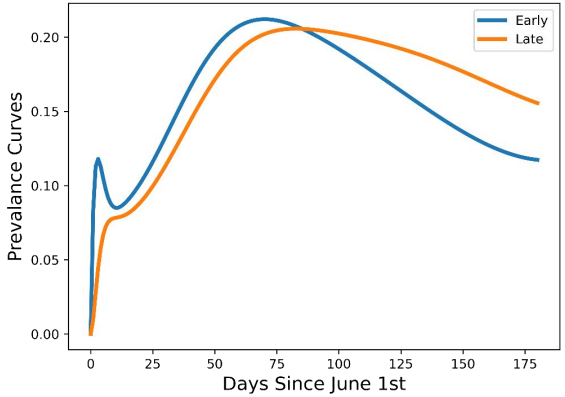




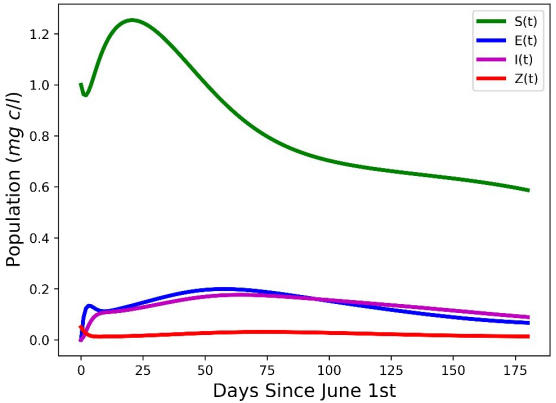
p = 0.70, k=0.1, sigma=0.35

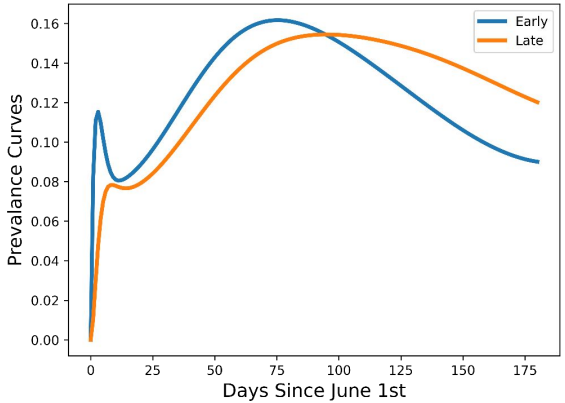
Everyone Gets Sick





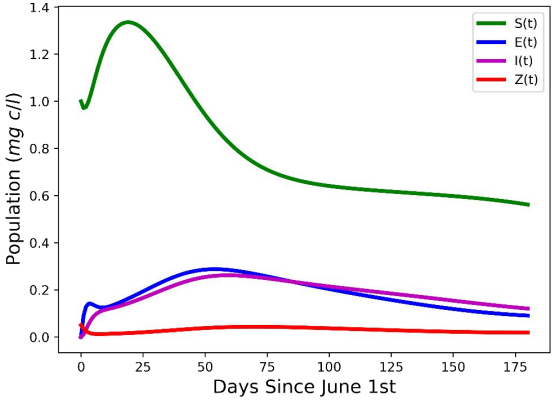
p = 0.55, k=0.1, sigma=0.35

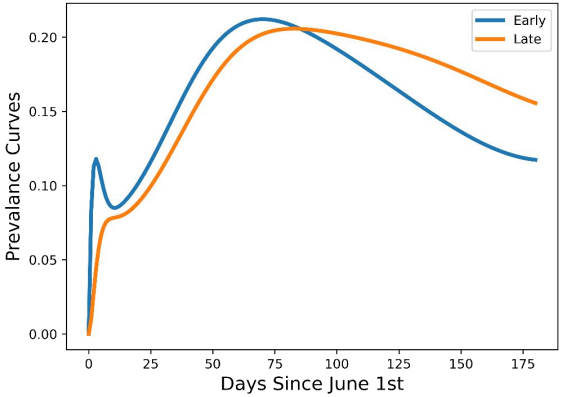




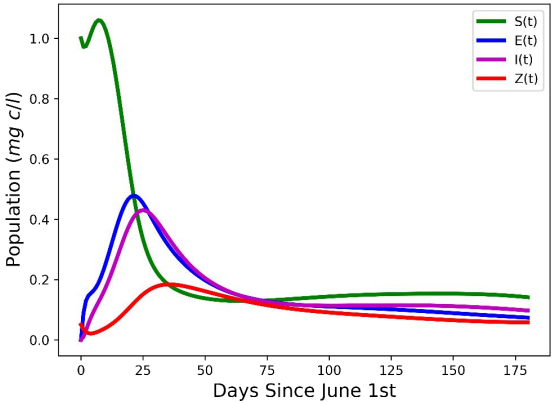
p = 0.70, k=0.0, sigma=0.35

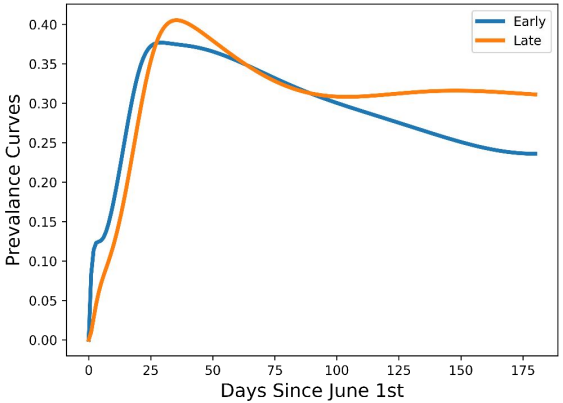
Too Many Spores?

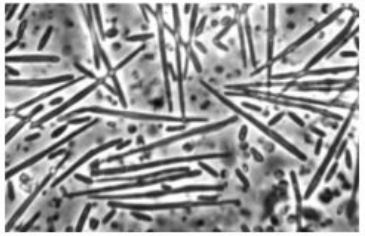




p = 0.55, k=0.1, sigma=0.35







p = 0.55, k=0.1, sigma=0.85

Conclusions

- Seasonality plays a large role
- Immune response is important, but not necessarily essential
- Predation influences peak structure, and is in line with “keep the heards healthy” hypothesis
- Spore release has dramatic effect on infection prevalence

Acknowledgments & References

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[1] M. Scheffer, S. Rinaldi, Y. A. Kuznetsov, and E. H. van Nes. Seasonal dynamics of Daphnia and algae explained as a periodically forced predator-prey system. Oikos, 80(3):519–532, 1997.

[2] M. S. Shocket, A. Magnante, M. A. Duffy, C. E. C´aceres, and S. R. Hall. Can hot temperatures limit disease transmission? A test of mechanism in a zooplankton-fungus system. Functional Ecology, 33:2017–2029, 2019.

[3] T. E. Stewart Merrill, S. R. Hall, and C. E. C´aceres. Parasite exposure and host susceptibility jointly drive the emergence of epidemics. Ecology, 102(2):e03245, 2020.

[4] T. E. Stewart Merrill, Z. Rapti, and C. E. C´aceres. Host controls of within-host disease dynamics: insight from an invertebrate system. The American Naturalist, 198(3):317–332, 2021.