BI 471/571: Population Ecology

Exam 2

5/20/2016

1 (30 points). Zombies are the walking undead. Slow moving ex-human horrors, they feast on human flesh and turn humans into zombies. Here we model zombie-human interactions over t = 100 timesteps using a predator-prey model:

$$dH/dt = rH(1 - H/K) - bHZ$$

$$dZ/dt = cHZ - mZ \qquad \text{(eq. 1)}$$

Assumptions:

- Zombies, Z, are walking undead; feed on human flesh
- Humans, H, are prey and cannot fight back
- Zombies bite humans to create more zombies
- Zombies are subject to natural mortality

a) Solve for the eigenvalues of the community matrix. Is the equilibrium of this system stable?

$$\frac{dH}{dt} = F(H,Z) = rH - \frac{rH^2}{K} - bHZ$$

$$\frac{dZ}{dt} = G(H,Z) = cHZ - mZ$$

Solve for equilibrium $\frac{dH}{dt} = 0 = rH - \frac{rH^2}{K} - bHZ$

$$0 = rK - rH - bZK$$

$$bZK = rK - rH$$

$$\frac{dZ}{dt} = 0 = cH\cancel{Z} - m\cancel{Z}$$

$$\text{or } \boxed{\hat{H} = \frac{m}{c}}$$

$$\boxed{\hat{Z} = \frac{r(K-\hat{H})}{bK} = rb - \frac{r}{bK}\hat{H}}$$

Solve for community matrix

$$\frac{\partial F}{\partial H} = r - \frac{2rH}{K} - bZ \qquad \frac{\partial F}{\partial Z} = -bH$$

$$\frac{\partial G}{\partial H} = cZ \qquad \frac{\partial G}{\partial Z} = cH - m$$

$$\begin{bmatrix} \frac{\partial F}{\partial H} & \frac{\partial F}{\partial Z} \\ \frac{\partial G}{\partial H} & \frac{\partial G}{\partial Z} \end{bmatrix}_{\hat{H},\hat{Z}} = \begin{bmatrix} r - \frac{2r\hat{H}}{K} - b\hat{Z} & -b\hat{H} \\ c\hat{Z} & c\hat{H} - m \end{bmatrix} = \begin{bmatrix} -r - \frac{2r}{K}\hat{H} - r + \frac{r}{K}\hat{H} & -\frac{bm}{c} \\ c\hat{Z} & 0 \end{bmatrix}$$

$$= \begin{bmatrix} -\frac{rm}{cK} & -\frac{bm}{c} \\ \frac{cr}{b} - \frac{cr}{bK}\frac{m}{c} & 0 \end{bmatrix} = \begin{bmatrix} - & - \\ + & 0 \end{bmatrix}$$

Trace < 0

Determinant > 0

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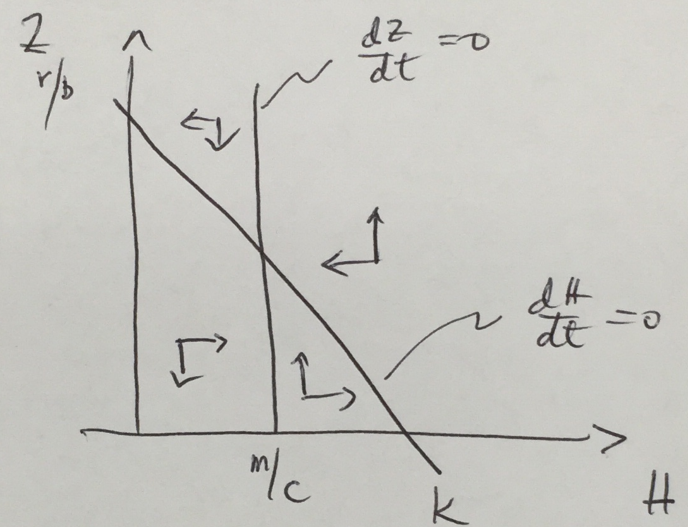
$\boxed{\text{Equilibrium Stable}}$

b) Carry out a phase plane analysis of this model. Label the intercepts.

$$\frac{dH}{dt} = 0 \quad \text{when} \quad Z = \frac{r}{b} - \frac{r}{bk}H$$

$$\frac{dZ}{dt} = 0 \quad \text{when} \quad H = \frac{m}{c}$$



$$\frac{dH}{dt} > 0 \quad \text{when} \quad rH - \frac{rH^2}{k} - bHZ > 0$$

$$r - \frac{rH}{k} > bZ$$

$$\boxed{\frac{r}{b} - \frac{rH}{kb} > Z}$$

$$\frac{dZ}{dt} > 0 \quad \text{when} \quad cHZ - mZ > 0$$

$$\boxed{H > m/c}$$

c) Plot the dynamics of the system eq. 1 in R assuming the following parameter set. Save your code and plot to be pushed to Github. What is the outcome of this particular zombie epidemic (i.e., do Zombies or Humans dominate this world)? What is the final human to zombie ratio in this world? Assume initial conditions are $h0 = 1$, $z0 = 0.1$ and the parameter set: $r = 1$, $K = 1$, $b = 1$, $c = 1$, $m = 0.1$.

Outcome:

Final ratio:

2 (30 points). Suppose humans discover a novel zombie parasite, P, which can be released globally and used as a biocontrol agent to cull the zombie horde. The dynamics of such a system can be represented as

$$dH/dt = rH(1 - H/K) - bHZ$$

$$dZ/dt = cHZ - mZ - dZP$$

$$dP/dt = eZP - nP \qquad \text{(eq. 2)}$$

Assume the same parameter set as above, $d = 1$, $e = 1$, $n = 0.1$ and initial conditions $p0 = 0.1$. Moreover, assume:

- Zombies, Z, are walking undead; feed on human flesh
- Humans, H, are prey
- Parasites, P, feed on zombies to create more parasites
- Zombies bite humans to create more zombies
- Zombies and parasites are subject to natural mortality

Plot the dynamics of the system eq. 2 in R and save your code and plot for Github. What is the outcome of this zombie epidemic now that humans have cleverly employed a biocontrol agent to fight back (i.e., do humans or zombies dominate this world)? What is the final human to zombie ratio in this world?

Outcome:

Final ratio:

3 (15 points). Choose **one** of the questions below to answer.

3a) Vaginal Microbiome

Several species of the bacterial genus *Lactobacillus* are often predominant in the vaginal microbiome of healthy, reproductive-age women.

- Describe the primary role of these bacteria in maintaining health of the reproductive tract (i.e., what compound do they produce, and how does this compound alter the vaginal environment)?

Lactobacillus spp. produce lactic acid as a byproduct of metabolism, creating an acidic environment (4-4.5) that is generally considered healthy. Smiley face if they say low pH inhibits growth of pathogens

- Explain how the human host may influence the relative abundance of *Lactobacillus* (e.g., during puberty).

Estrogen produced by the host is believed to drive higher levels of Lactobacillus and lower vaginal pH (estrogen ramps up during puberty and remains high throughout reproductive age. Smiley face if they point out that estrogen thickens the vaginal epithelium and/or leads to production of glycogen, which is thought to be the main substrate of lactic acid bacteria

- Hypothesize why individuals display differences in the composition and dynamics of their microbiota.

Any reasonable answer relating any of the following — host physiology/genetics/behavior, microbial communities, environment — will do

3b) Urban Microbial Ecology

Describe at least three ways humans can manipulate microbial communities in human-dominated environments.

Some things Dr. Hartmann mentioned are physically transporting strains (e.g., yeast for winemaking), altering the temperature, altering the reaction time, providing different nutrients, encouraging flocculation/settling (all of those are in bioreactors), and using bioactive chemicals (antibiotics/antimicrobials). Andy Siemens also discussed the effect of light, so any answers involving light could also be valid.

3c) Skin Microbiome

What experimental approaches are being used to test hypotheses about microbial community assembly on the skin?

Dr. Ashley Bateman is Test the consequences of controlled dispersal and environmental selection on the community structure and membership of the skin microbiome with a series of reciprocal transplants between 3 skin sites on 10 human individuals. Specifically, she is exploring whether intact, natural skin communities are colonizable by microbial communities from other skin sites on the same host, without prior disinfection. Methods include bacterial DNA sampling, extraction, amplification, sequencing, and analysis.