BIOL285 Spotted lanternfly article lab

Here you will work in pairs to investigate the spotted lanternfly life-cycle model. You will complete 5 tasks and write a super brief report containing your answers and key calculations. Begin by opening the preprint version of **Strömbom & Pandey 2021** and read the abstract, then proceed with the tasks below.

1. Specify the stages we use in this model and explain what the key parameters s_{PO}, $s_{NP,}$ s_{AN} and F represent.

2. Find Table 1. The first row in the table represents the parameters that correspond to No Control of the lanternfly, i.e. the parameter values for the population when it is growing freely without any management efforts. One of the main results of the paper is that in this case the lanternfly population's annual growth rate is 5.47, i.e. the population is growing by approximately 447% (5.47-1=4.47) every year. By using the values in this first row of the table verify this growth rate in two ways:

A) By inserting the parameter values into the matrix in Figure 1 on page 2 and calculate the dominant eigenvalue of this matrix to the power 4. I.e. if the matrix is called M, calculate eigenvalues M^4.

B) Via equation (2) on page 2 in the paper.

3. From above we know that the annual growth rate of the lanternfly in the absence of controls is 5.47. Assume that 100 adult lanternfly came to the US at time T=0 and use formula (3) on page 2 to calculate how many lanternfly would be in the US after 9 years according to the model.
Note: It is believed that the lanternfly came to the US in 2012 so the number you just calculated can be a considered an estimate of the number of adult lanternfly that will emerge late this summer and fall (2021).

4. One issue with several of the biological studies that have been used to assess the efficacy of the control measures is that in the experiments they treated all, or at least an overwhelming majority, of all lanternfly present. When applying any control measures in the real world it is likely that the control measure will not get to every single lanternfly in the region where the control is deployed, and over larger geographical areas the proportion that manage to evade the control may be quite large.

Formula (4) on page 2, also paste below, can be used to calculate the growth rate of a lanternfly population where a proportion **p** of the population is being treated, and thus a proportion **1-p** not treated, with a control measure that results in parameter values s^x_{PO}, $s^x_{NP,}$ s^x_{AN} and F^x for the treated part of the population. The No Control parameter values s_{PO}, $s_{NP,}$ s_{AN} and F from Table 1 apply to the not treated proportion of the population.

$$\lambda^x(p) = (s^x_{PO}p+s_{PO}(1-p))(s^x_{NP}p+s_{NP}(1-p))(s^x_{AN}p+s_{AN}(1-p))(F^xp+F(1-p)).$$

Therefore, if we know the parameter values when the control is applied (s^x_{PO}, s^x_{NP}, s^x_{AN} and F^x) and the proportion **p** we can treat, then we can calculate the population growth rate with incomplete delivery of this control measure. For example, if we can treat 50% of the population (p=0.5) with a control measure that yields parameter values

$s^x_{PO}=0.40$, $s^x_{NP}=0.47$, $s^x_{AN}=0.13$, and $F^x=27.21$

and the no control parameter values (From row 1 in Table 1) are

$s_{PO}=0.62$, $s_{NP}=0.74$, $s_{AN}=0.25$, and F=47.73

then the growth rate with incomplete delivery can be calculated via

(0.40*0.5+0.62*(1-0.5))*(0.47*0.5+0.74*(1-0.5))*(0.13*0.5+0.25*(1-0.5))*(27.21*0.5+47.73*(1-0.5))

Input:

$(0.4\times0.5+0.62\,(1-0.5))\,(0.47\times0.5+0.74\,(1-0.5))$
$(0.13\times0.5+0.25\,(1-0.5))\,(27.21\times0.5+47.73\,(1-0.5))$

Result:

2.196660015

so in this case the annual growth rate will be 2.197, i.e. the population will still increase by about 119.7% each year, which will not solve the lanternfly problem. But perhaps this control measure could work to decrease the population if only we could treat a larger proportion of the lanternfly population? And if so, maybe formula (4) can help us figure out what proportion we need to treat.

Remember that if the annual growth rate (eigenvalue) is less than 1 the population will decline, so if we solve ***RHS of formula (4) < 1 for p*** then we should get info about the smallest proportion **p** we must treat for population decline to occur. For the example above we do this as follows

solve (0.40*p+0.62*(1-p))*(0.47*p+0.74*(1-p))*(0.13*p+0.25*(1-p))*(27.21*p+47.73*(1-p))<1 for p between 0 and 1

Input interpretation:

solve $(0.4\,p + 0.62\,(1-p))\,(0.47\,p + 0.74\,(1-p))\,(0.13\,p + 0.25\,(1-p))\,(27.21\,p + 47.73\,(1-p)) < 1$

$0 \le p \le 1$

Result:

$0.846363 < p \le 1$

So, for this particular control measure to decrease the population we must treat at least 0.846363 of the population with it, i.e. at least about 85% of the population.

A) Recently a new study was published where they found that if the experimental population was treated with a particular insecticide the survival rate from over-wintering to post-diapause eggs was $s^x_{PO}=0.30$, the survival rate from post-diapause eggs to nymphs was $s^x_{NP}=0.20$, the survival rate from nymphs to adults was $s^x_{AN}=0.10$, and each lanternfly produced $F^x=10$ eggs on average. If we can treat p=0.4 (40%) of the population with this control, what will the annual growth rate be? Will we be able to get the population into decline?

B) If in A) you found that treating 40% would not be enough to get the population into decline find the smallest proportion **p** we have to treat in order for that to happen.

5. The X Department of Agriculture (XDA) are excited. They have conducted an experimental study and found that their new control measure kills every single treated lanternfly in every stage, that is, the parameters for this control is $s^x_{PO}=0$, $s^x_{NP}=0$, $s^x_{AN}=0$, and $F^x=0$.

The XDA are confident that they will be able to deploy this control in up to a third of the counties infected with the lanternfly in the US every year, and thereby up to a third of the total US lanternfly population (33% or p=0.33) every year. They are confident that at this rate the lanternfly will be eradicated from the US in just a few years. Are they right? Explain.