

Mad Dogs and Chicken Heads

Modelling Disease Outbreaks and Vaccination Campaigns

by

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Part I – Introduction

Doris had been looking forward to the trip for weeks. This year Luna, her young lab retriever, was old enough to join her for the summer holidays, and grandpa Ueli had managed to find a dog-friendly campsite by Lake Brienz. Ueli could be grumpy, but he liked her company and always had good stories to tell. Having grown up in the city, Doris enjoyed the fresh air in the Swiss Alps despite sharing a cramped caravan with her grandpa.

One evening at dusk, after she and grandpa had cleared away dinner and settled down for stories before bedtime, Doris noticed an animal scuttling around a trailer at the other end of the campsite. It went quiet again, but then a bushy tail gave it away; a fox! When she pointed it out to Ueli, his gruff response surprised her: “Don’t go near it! Can’t trust those animals. Why do these fools leave their dinner leftovers out in the open for the foxes to help themselves? You do know they carry diseases, right? Last thing I need is for you or Luna to get bitten by a rabid fox.”

“But Grandpa,” Doris replied, “Luna is vaccinated. They wouldn’t have let us onto the campsite otherwise! And anyway, only animals catch rabies, so it’s not a problem for us.”

Ueli snorted, “You have no idea. Alright, Switzerland has been officially rabies-free for 20 years. But did you know that three people died from rabies in 1977, and dozens more across Europe?”

“You’re joking.”

“I’m not. Sometime during the war, rabies emerged in Poland and started to slowly spread across Europe where it hadn’t really been seen for almost 100 years. Mostly wild foxes, badgers, deer and a few stone martens were infected, but also dogs, cats and cattle. By the time the epidemic crossed the border from Germany in 1967, we were well prepared to test animals for rabies, but there wasn’t much we could do to fight it other than kill the animals. Trouble is, for months after an animal, or human for that matter, is infected, nothing much happens; they look more or less normal. Then suddenly symptoms are obvious. Animals are agitated and frothing at the mouth; and by that point, the disease is almost always fatal within days. We had to watch helplessly as the number of rabid foxes reported to the authorities shot up to over a 1200 a year in 1975 and ’76. The number of infected pets and domestic animals also started to increase to around 200 cases every year and stayed at that level into the mid-eighties. That’s how those people died: one man was bitten by a cat, a vet caught rabies from an infected cow, and a dog breeder caught it from one of his own dogs. It’s tragic because by that time we had long known how to give people post-exposure treatment that could have saved them. I suppose the animals that had bitten these men showed no signs of rabies at the time. These deaths gave a big boost to a slightly crazy programme: to eradicate rabies by vaccinating wild foxes.”

“Vaccinating wild foxes?” Doris asked. “You mean, like giving them flu jabs?”

To be continued ...

Watch the following video and read the following article, then answer the questions below.

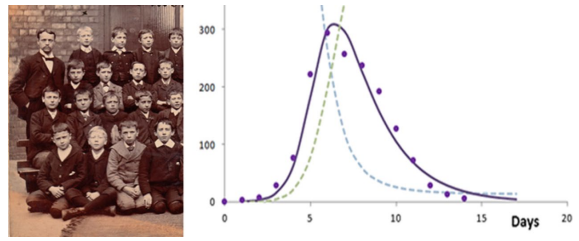
- *The Strange—but Necessary—Task of Vaccinating Wild Seals*. Vaccination of endangered Hawaiian Monk seals against morbillivirus in the wild. Running time: 2:59 min. Produced by National Geographic, 2016. <<https://youtu.be/M26kh8FS4Mw>>
- Yong, E. 2015. That time Europe air-dropped vaccine-loaded chicken heads to bait rabid foxes. *The Atlantic*, Dec. 1, 2015. <<https://www.theatlantic.com/science/archive/2015/12/that-time-europe-air-dropped-vaccine-loaded-chicken-heads-to-bait-rabid-foxes/417951/>>

Questions

1. Rabies is a zoonotic disease. What does that mean for its management? What other zoonotic diseases have made the headlines in recent years?
2. Why does it take so long after infection for an animal or human to show symptoms?
3. Doris didn't know that rabies can affect humans, and her grandpa only knew of historic cases. Has rabies stopped being a problem for us?
4. Why is it challenging to vaccinate wild animals? Consider the differences between Hawaiian monk seals and European foxes.
5. How do you know whether you have vaccinated enough animals? Winkler and Bögel (1992, linked from Ed Yong's article) say 60–70% of the fox population needed to be vaccinated to eradicate rabies. How might they have arrived at that figure?

Part II – Influenza in a Boarding School

Note: The following questions require the use of the MS workbook “rabies_epidemiology_1.xlsx.” That workbook contains two worksheets whose tabs are labelled “introduction” and “boarding school.” Additional information and guidance is provided in Part II of the PowerPoint presentation associated with this case study.



Questions

Worksheet “boarding school,” Slide 26:

1. Adjust β (the transmission coefficient) and γ (the recovery rate) until your prediction for the number of ill boys matches the real-world data well. The easiest way to do this is to click or click and hold on the space either side of the slider handle (for larger steps) or on the arrowheads framing the slider (for finer steps), rather than dragging the handle itself.
2. Report your values for β and γ , include a screenshot of your curve (crop it to show just the curve), and if you have done a least square analysis, report your sum of squares.

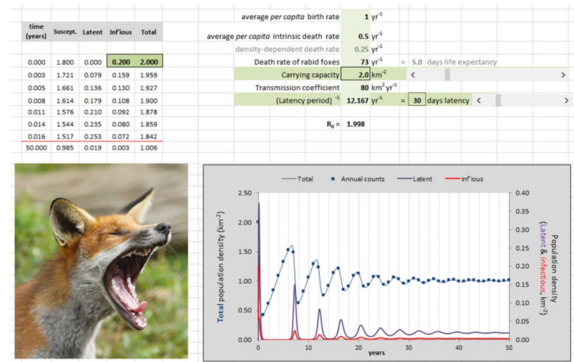
Worksheet “boarding school,” Slide 33:

3. From your values of β and γ , calculate the basic reproductive rate R_0 and the critical population size S_T for influenza.

Part III – Modelling Rabies in Foxes

Note: The following questions depend on the use of a second MS workbook, “rabies_epidemiology_2.xlsx.” That workbook contains two worksheets whose tabs are labelled “fox rabies” and “with vaccination.” Additional information and guidance is provided in Part III of the PowerPoint presentation associated with this case study.

Start by looking closely at what is plotted in the graph on the worksheet “fox rabies,” paying attention to which axis shows what. Then use the sliders to vary carrying capacity and latency. Observe how the patterns change and consider what they mean “in the real world.”



Questions

Worksheet “fox rabies,” Slide 43:

1. The model predicts different types of long-term outcomes for different combinations of latency periods ($1/\sigma$) and carrying capacities K . Describe these outcomes for combinations of K and ($1/\sigma$) that fall within areas A, B and C of the plot (see Figure 1, right).

Some extra help here: Adjust the sliders in the model so you arrive at combinations of latency periods $1/\sigma$ and carrying capacities K that lie in the regions A, B or C. Try to interpret what the curves for total and infectious populations mean. Predict what will happen in the long term by extrapolating the trend you see. Compare total population size at extrapolated “ $t = \infty$ ” with the carrying capacity. Check R_0 to see if the disease spreads or comes to a halt.

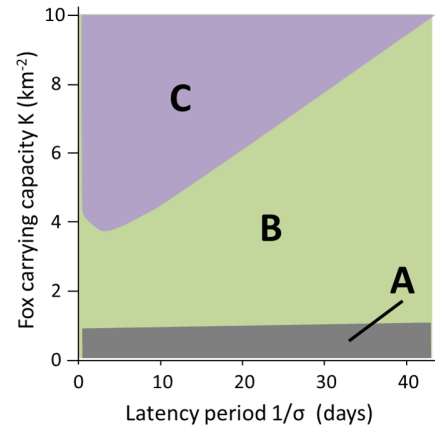


Figure 1. Regions A, B, and C.

Worksheet “with vaccination,” Slide 48:

2. For a range of carrying capacities from 0–10 km^2 , find out “empirically” what minimum percentage of the population needs to be vaccinated to wipe out rabies. In a diagram, plot those points and indicate which is the “safe” area. (See Figure 2 for an illustration of the *general* idea; however, the *actual* plot will *not* look like this).
3. Considering that the density of foxes in Europe is in the range of 1–4 foxes km^2 , what is your recommendation for how to eradicate rabies?

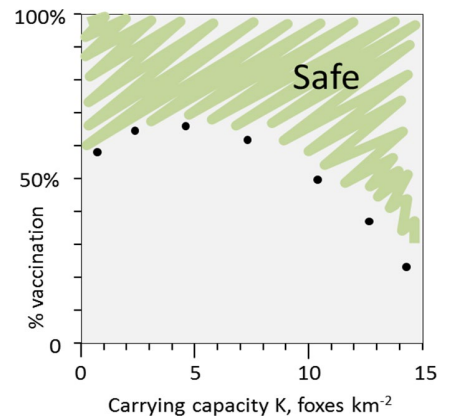


Figure 2. Sample figure for illustration only.

Epilogue

“Vaccinating wild foxes?” Doris asked. “You mean, like giving them flu jabs?”

“Well, not quite; people tried that, but setting up syringes in the woods was just a bit too risky. Think oral vaccination! We were lucky that just a few years before, the Americans had started testing how to hide vaccines in sausages so that foxes would gobble them up. A trial on a small Alaskan island had worked really well. It wasn’t pursued in the end because rabies started to decline naturally in the United States, but when rabies really took off in Europe, the Americans shared what they had learned. Over here, we used chicken heads as baits. A few thousand at first, scattered around by hand, and over the next years millions more by helicopter.”

“Looks like it worked; I haven’t heard anything about rabies outbreaks. I’ve always wondered why we had to give Luna a rabies shot.”

“Yes it worked, but it took a long time. All over Europe, we still keep vaccinating foxes and dogs, and we have to watch out for dogs that come from outside. The Americans have worked out how to vaccinate raccoons and coyotes, but there are also bats that can carry rabies, and nobody knows how to bait and vaccinate a bat. There’s a tough nut for you! But it’s bedtime now.”

That night Doris had strange dreams of bats and flying chicken heads.

