TIEE

Teaching Issues and Experiments in Ecology - Volume 19, December 2023

Flying Foxes and Uncertainty

The primary learning objectives of this module are for students to be able to:

- Understand sources of uncertainty and how they affect ecological decision making
- Analyze how representations of uncertainty may need to differ between end users
- Evaluate how presenting forecast uncertainty may be an ethical responsibility

Assigned reading

This module is based upon the following academic paper. Reading the full paper is optional, but may enhance understanding of the forecast model used in this case study:

- Ratnayake, H. U., M. R. Kearney, P. Govekar, D. Karoly, and J. A. Welbergen. 2019. Forecasting wildlife die-offs from extreme heat events. Animal Conservation **22**: 386–395. https://doi.org/10.1111/acv.12476

Additionally, two news stories may provide useful context for the effect of heatwaves on flying foxes:

- “A Heat Wave in Australia Killed 23,000 Spectacled Flying Foxes”
    - Written by Jason Bittel (2019) and published by the *National Resources Defense Council (NRDC)*
    - https://www.nrdc.org/onearth/heat-wave-australia-killed-23000-spectacled-flying-foxes
- “How one heatwave killed 'a third' of a bat species in Australia”
    - Written by Frances Mao (2019) and published by the *British Broadcasting Corporation (BBC)*
    - https://www.bbc.com/news/world-australia-46859000

For background on ethical considerations in forecasting, we recommend these two resources that both originated from the COVID-19 pandemic:

- “Ecological forecasting ethics: lessons for COVID-19”
    - A guest post on the *Dynamic Ecology* blog, written by Record et al. (2020)
    - https://dynamicecology.wordpress.com/2020/06/08/ecological-forecasting-ethics-lessons-for-covid-19/

- "Five ways to ensure that models serve society: a manifesto"
    - A short "comment" article in the journal *Nature*. Written by Saltelli et al. (2020)
    - https://www.nature.com/articles/d41586-020-01812-9?WT.ec_id=NATURE-20200625

Case study

Flying foxes are not foxes at all!

Flying foxes (*Pteropus sp.*) are a genus of bat that includes around 65 different species, found commonly throughout tropical islands in Asia and Oceania (Figure 1). Some of these species are among the largest bats in the world, with wingspans that range up to 1.5 meters (5 feet). Unlike most bat species, flying foxes use sight, rather than echolocation to navigate, despite the fact that these bats are still predominantly nocturnal. Flying foxes have a diet composed primarily of flowers and fruit, and they consequently play an important role in seed dispersal and pollination for a variety of plant species across Australasia. Unfortunately, nearly half of all flying fox species are experiencing declining populations. The International Union for Conservation of Nature and Natural Resources (IUCN) has classified 15 species of flying fox as "vulnerable" to extinction, and an additional 11 species as endangered.

Flying foxes are social animals and tend to roost together during the day, often congregating in a group of trees that is called a "camp." Camps can sometimes be quite large, with up to 100,000 individual bats. Within the camps, bats have the opportunity to find mates, feed their young, and rest during the day.

Figure 1: Photo of a grey headed flying fox, taken by Leo on flickr. Licensed under CC BY-NC-SA 2.0.

Mass mortality events

Flying foxes are highly sensitive to extreme heat: when temperatures rise above 42 ºC (107.6 ºF), colonies of bats have been known to die in massive quantities. For example, one heatwave in Queensland killed 45,500 flying foxes in a single day (Bittel 2019). To help protect these species, volunteers will go out with firetrucks and wheelbarrows and spray down the trees with water or collect bats off the ground to try to save them.

Flying fox forecasts

Ratnayake et al. (2019) developed a forecast of bat die offs, based on weather forecasts, to help plan rescue missions in advance and target the areas that need the most help. Their simple forecast model predicts that a mortality event will occur if the forecasted temperature is greater than or equal to 42 ºC, and no mortality event will occur if the temperature is less than 42 ºC.

You can get a sense of the accuracy of these forecasts from the data presented in Table 1. When weather forecasts indicate that temperatures will be ≥42.0 ºC the following day (24-hr forecast), it is much more likely that flying fox colony death will occur (37) vs. not occur (8). Conversely, when air temperatures are forecast to be < 42 ºC, it is more likely that flying fox death will not occur (42) rather than occur (15). The same is true using 48-hr forecasts (Table 1), though you may expect that weather forecasts made two days in advance would be less accurate than forecasts made the day before.

Table 1: Relationship between forecast air temperature and flying fox die offs (Ratnayake et al., 2019). Table reproduced with permission from the publisher.

Forecast air temperature ≥42.0°C	Occurrence of death in a flying-fox colony	
	Yes	No
24-h forecast		
Yes	37	8
No	15	42
48-h forecast		
Yes	44	19
No	8	31

Discuss with a neighbor (1):

What types of ethical considerations do you think are necessary when developing this sort of forecast? In what way are they relevant?

Here are a few examples of potential ethical issues to begin your discussion:

- Conflicts of interest: a forecast designed to benefit one user may have disadvantages for other groups
- Uncertainty: no forecast is 100% correct. How uncertainty is represented (or omitted) may have consequences for the use of the forecast
- Sins of omission vs. commission: Is it better to provide a forecast even if you know it is not perfectly accurate? Or to *not* provide the forecast and risk being unprepared for something your forecast could have predicted?

Forecast uncertainty

Today, we are going to be focusing on the subject of uncertainty. Forecast uncertainty comes from many sources, including:

- Driver uncertainty: uncertainty in the inputs to the forecast model (an example is the uncertainty inherent in weather forecasts)
- Process uncertainty: uncertainty that the model itself is correct (for example, do we need to consider factors other than temperature when predicting bat die-offs?)

- Parameter uncertainty: uncertainty in the parameters of this model (here, the 42 ºC cutoff is an example of a parameter).

The flying fox forecasts developed by Ratnayake et al. are often, but not always, correct in their predictions of mortality events. Figure 1 shows the outcome of forecasts for one heatwave event (4 January 2014). During this heatwave, some mortality events were correctly predicted (“Hits”), some mortality events were predicted but did not occur (“False alarms”), some mortality events occurred in places where they were not predicted (“Misses”), and some areas were correctly predicted to not experience mortality events (“Correct negatives”). As you can see from this example figure, these flying fox forecasts are relatively good at predicting flying fox die offs, but they are not perfect (that is, they contain uncertainty!).

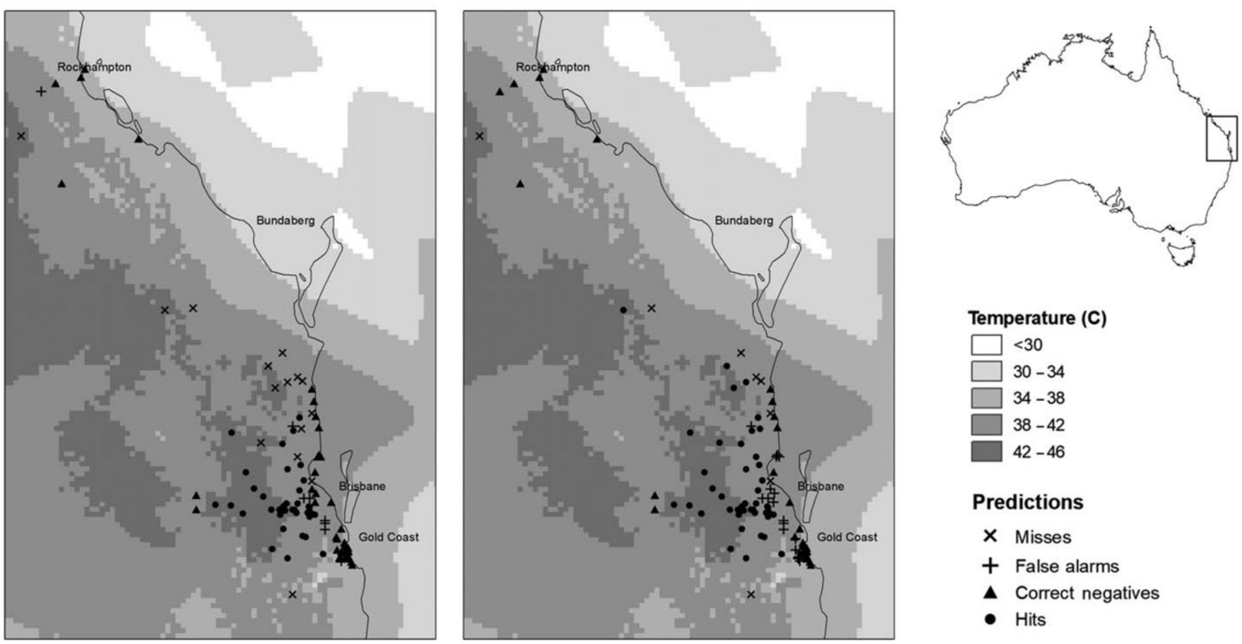

Figure 1: Flying fox heat stress forecasts from Ratnayake et al. (2019), reproduced with permission from the publisher. Here, different levels of shading indicate the observed air temperature, and symbols indicate whether or not bat mortality forecasts were correct. “Misses” (“X”) are cases where bat mortality conditions happened but were not forecast, “False alarms” (“+”) are cases where bat mortality conditions were forecast but did not actually occur, “Correct negatives” (▲) are cases where bat mortality conditions did not happen and were not forecast to happen, and “Hits” (●) are cases where bat mortality conditions were correctly predicted.

Discuss with a neighbor (2)

- What do you think would be the greatest sources of uncertainty in this forecast?
- Why does the uncertainty in this forecast matter?
- What happens if you (the forecaster) predict that a mortality event will occur (temperature will exceed 42 ºC) and it does not? What happens if you predict that a mortality event will not occur and it does? How might you take these different consequences into account?

Uncertainty visualization

Forecast uncertainty is notoriously difficult to communicate: your goal is to convey a range of likely outcomes, without overwhelming your audience with too much technical information. In this case, the challenge is particularly difficult because the forecast is for a broad geographic region. Here are some useful methods that people often use to visually communicate forecast uncertainty:

- Map of a likelihood metric across space (e.g., percent chance of a mortality event)
- Map of a summary index across space (e.g., low, medium, or high likelihood of a mortality event)
- Graph of likelihood metric (e.g., percent chance of a mortality event) over time for a given place
- Graph of summary index (e.g., low, medium, or high likelihood of a mortality event) over time for a given place
- Graph of your predicted variable of interest (e.g., air temperature) over time, with a range of uncertainty (e.g., error bar)

Working individually

- Make a list of 3–5 relevant people or organizations that might be interested in these forecasts. For the sake of this module we will call these people or organizations “end users”
- Pick one end user to focus on: what is this end user hoping to accomplish? Why are they interested in the forecasts? How do their motivations inform how they would like to receive this information?
- Now that you have decided what an end user wants to learn from a forecast, what would be the best way to visually communicate the forecast to that end user? Quickly sketch an example visualization for this end user

Now turn to a partner

- Partner 1: Show/explain to your partner the forecast visualization you designed
- Partner 2: Playing the role of the end user *you chose*, respond to the forecast visualization that your partner developed. Note: this is probably not the end user they originally developed the forecast for! What questions do you have about this forecast output?
- Repeat, with Partner 2 sharing their visualization and Partner 1 playing the role of their chosen end user
- Discuss:
    - What (if any) issues arose when you tried to use this forecast output for the new audience?
    - Now imagine a scenario where you portrayed forecast uncertainty poorly and this caused an end user to make a bad decision. Do you have any responsibility for their actions? Should you be held accountable?

References

Bittel, J. 2019. A Heat Wave in Australia Killed 23,000 Spectacled Flying Foxes. *NRDC*. Retrieved from https://www.nrdc.org/stories/heat-wave-australia-killed-23000-spectacled-flying-foxes

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