

## Population viability analysis

Basically, what we're interested in is how "viable" a population is. One way of looking at this is to ask "how long will this population survive in the wild?", and "how big do I need to make a reserve in order to be sure that the species will survive?"

An important preliminary note: This is NOT a "cure-all". The method outlined here only gives an "indication" of what might happen. This will be pretty obvious as we go on.

Because it's so easy to do silly things with this, the authors pick an example that is very simple in its makeup (well, comparatively speaking).

### **The red kangaroo, *Macropus rufus*:**

This is a simple system in that we have:

- no seasonality, breeding through out the year, no seasonal population structure, (and few predators).
- Should mention that this is a herbivore, so its food supply is easier to monitor.

Rainfall:

- Varies quite a bit, (high variance).
- About 30% of the time rainfall is 50% above or below average, leading to droughts and/or floods.

Plants:

- Respond to rainfall by growing.
- Increment to plant biomass (ungrazed) is given in the text on page 195, and is a function of rainfall and standing plant biomass (how many plants are already there).

Kangaroos:

- Do two things with the plant biomass:
  - 1) graze to meet energy requirements.
  - 2) graze to produce more kangaroos.

From studies of plants and kangaroos we have estimates of all these quantities. For example, an “average” kangaroo will eat:

$$0.95(1 - e^{-V/34}) \text{ kg dry weight of pasture}$$

0.95 represents the “satiating diet”, or the amount of plant material per day a kangaroo would eat if it could eat as much as it wanted to, and  $V$  is the standing crop (as defined above).

If there is a mix of foods, this figure varies (see text).

Kangaroo populations obviously respond to food availability (or other limiting resource). This is called a “numerical response”, and for red kangaroos is estimated as follows:

$$r = -a + c(1 - e^{-dv})$$

Here,  $r$  = exponential rate of increase (yearly),  $a$  = maximum rate of decrease (how fast population crashes when there is no food),  $c$  = rate at which this is offset when there is enough biomass for a satiating diet, and  $d$  is an index of grazing efficiency.

So, for example, Caughley, uses this equation and plugs in estimates for  $a$ ,  $c$ ,  $d$  and  $v$  to get:

$$r = -1.6 + 2.0(1 - e^{-0.007V})$$

This says that the rate of increase varies between 0.4 (when pasture biomass is abundant) and -1.6 (when there is no pasture biomass)

- plug in 0 for  $V$ , and the 2.0 disappears (anything raised to the 0 power = 1).

- the higher  $V$  becomes, the closer to 0 the term with  $e$  becomes (just try a couple of value with your calculator).

An application of this (showing the effect on  $r$ ) can be seen in figure 7.3

This gives us the basic setup for the next step, where we try to estimate how kangaroo populations behave. This was done by computer simulation.

The authors blithely assume that rainfall follows a normal distribution (they should justify this! - it's pretty easy to simulate rainfall using almost any distribution one wants, including re-sampling (i.e., randomly sampling actual data)).

The method presented to simulate random normal numbers is awful. There are MUCH better (and easy to implement) methods available.

In any case, the basic approach used was as follows:

- estimate rainfall for a three month period (this is where the normal distribution came in) by randomly choosing a rainfall number.
- from this get an estimate of the increase in biomass.
- this, in turn, allowed an estimate of the impact on kangaroo numbers.
- finally, from the adjusted kangaroo population the plant biomass figures were adjusted (i.e., to the changing grazing pressure).

The result of this simulation is in figure 7.4, page 200. Notice that kangaroo numbers fluctuate quite a bit, depending on rainfall (at one point getting pretty close to 0 kangaroos/km<sup>2</sup>).

We can now take this information and try to figure the “persistence” of this population. In particular, we’ll try to figure out how large a reserve must be to conserve a population of red kangaroos for a specified number of years.

- Since the model was based on a population of wild Kangaroos, we must stipulate that the reserve we set up has the same climate as this wild population, furthermore, we insist:

- no kangaroos leave or enter the reserve
- that fire has no impact (unlikely in Australia)
- that there are no predators
- no competitors to the red kangaroo are in our reserve
- surface water (drinking water) is not in short supply

- Now do we see why this type of analysis is so tenuous? But we’ll keep going.

- From the model (computer model) above, we can realize that the average number of kangaroos per hectare is 0.45. A simple calculation shows that this comes out to 45 kangaroos per square kilometer.

- First, lets try to figure out how long this population will persist

based on the size of the reserve.

- The extinction threshold is the density at which the population dies out. Obviously, in terms of population, this is 1 kangaroo. This translates to a density of .1/ha if the reserve is 10 ha in size, and .01/ha if the reserve is 1 square km. Notice how the densities change with the size of the reserve.

- So, we can estimate the persistence of the population by doing more simulations. We:

- Run the above simulation and find out how long (on average) before the population crosses the extinction threshold.

- In other words, we pick a reserve size, then run our simulation once. We run it until our computer population of kangaroos goes extinct.

- This is our first number (our first estimate for extinction time)

- Repeat this simulation, get another number, and average.

- Do this 100 times (these days it'd be easy to do 100,000 times or more).

- We can then run the whole thing again changing our reserve size.

- Finally, we can plot the "average" time to extinction against reserve size (figure 7.5).

- Okay, so now we have an initial idea of how our reserve will do, depending on size.

- Not terribly accurate. Remember, this is based on "averages". A single run might indicate extinction in 5 years instead of 400. There is a lot of year to year variation which gets covered up by this method.

- Can we get an estimate of how badly we did? (Yes, or we wouldn't ask the question).

- We'll try not to get quite as technical as the book. Let's take a look at all runs for a specific size.

- Remember, for each “size”, we did 100 runs to try to get an “average” time to extinction. Now we’ll graph EACH of these runs. This is given in figure 7.6.

- Notice how a lot of individual runs had a very short time to extinction. It’s the few runs at longer times that are pulling the average up.

- Another way of looking at this is to realize that if our model has any semblance to reality, that most of the times, our population won’t last long (our average is not in the middle!) [illustrate].

- a better estimate might be the median - this gives us the number of years for which 50% of our runs go extinct. (It’s not the same as the mean!!!)

- The authors use the resemblance of figure 7.6 to the exponential distribution to derive this analytically. One could, presumably, get this information just as quickly from the original simulations (it’s not at all clear why they didn’t get the median this way).

- overall, the median is only 69% as long as the mean. This indicates that the median time to extinction is much shorter than the mean time to extinction.

- this indicates that we really need to be careful in designing our hypothetical reserve (the median is probably much better than the mean here).

- Note that we could also easily use quantiles (or percentiles). For example, why bother figuring out the median - let’s pick the 25<sup>th</sup> percentile, that figure at which 25% of our runs indicate extinction.

- Now, let’s turn this on it’s head and calculate the probability of persisting 100 years based on reserve size. We won’t go into the details here, except to note that we’re just manipulating the above stuff a little. This is given in figure 7.7.

- From this we can \*finally\* figure out how big a reserve needs to be if we want a probability of .999 (99.9%) that our kangaroos will still be around in 100 years.

- This gives us a figure of 69 hectares.
- Remember, a lot of stuff and assumptions went into this estimate.
- Do we want an error estimate? It'd be nice to have some estimate for this. We could probably do something with a statistical technique called bootstrapping (we could, for instance, estimate the error rate from our runs above).
- But let's remember that we're getting further and further from reality here. It's probably best to follow something like the rule of thumb the authors provide.
  - We want a comfortable margin of error (we want to be pretty sure that we did things right and our population will survive).
    - Double our estimate to allow for influences we didn't model.
    - Double again to allow for stupid mistakes in field work (maybe someone counted two kangaroos for every single kangaroo, or transposed a figure somewhere). Beer in Australia is quite good!
    - Double again for stupidity in management by future biologists and rangers (this, unfortunately, happens quite a lot).
- So we wind up with  $8 \times 69$  ha, or about 550 ha for the size of our reserve (that's 5 square kilometers).
- This is obviously not terribly scientific, but it clearly points out the shortcomings of this method.
- Nevertheless, if we don't have any better idea of how to get a reserve size, this might be a good start.
- We skipped over a few details, but that's okay. We just wanted to get an idea of how this method might work.
- Next time we'll generalize this (i.e., how can we use something like this for "any" species).