

## POPULATION MODELS

# Environmental Stochasticity, Part 1

Tony Starfield

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I want to kick off by thinking about how you're going to report back to the caliph on your model.

It seems to me that probably what you're going to tell the caliph is, no problem with rocs. It looks as though, given the information that we've got, the roc population is going to grow rather than decline over the next thousand years. It might grow to 1200, 1300, 1400, 1500, somewhere in that ballpark. You probably also want to tell the caliph that in terms of research, if he's going to fund only one research project, it makes most sense to fund the project on clutch size. That is the crucial parameter in the model. You might have taken it a little further and said, if you're going to do two projects, fund clutch size and fund the project on silver bullets.

Now, the way in which you report back to the caliph could be important. If you go back to the caliph and say, "My model tells you that in the year 2000 you're going to have 1352 rocs," that's not a very useful way to report back. If you go back and say, "Remember, a model is an if-then statement, given the information we've got on rocs, given everything you tell me, if I use these values and make these assumptions, then it seems as though the population is going to grow into the range of 1300 to 1500." That's not only a more cautious statement, it's a more defensible and accurate statement.

And I'm going to show you now why it is terribly important never to stick your neck out and say that your model gives the answer.

Because it turns that while you were putting the final touches to your report, and while you were thinking about how you were going to spend your bag of gold, Scheherazade was reading love poetry to the caliph. And she was reading a particular love poem which went like this, "A flask of wine, a loaf of bread, and thou besides me in the wilderness." Now, some of you might remember that as a paraphrase of the Rubaiyat of Omar Khayyam. I think the next line is "and wilderness is paradise and now." But there's this very romantic idea of having two lovers in the desert with a flask of wine and a loaf of bread.

But for the purposes of our modeling exercise, the next line that Scheherazade read went something like this, "Midst the stench of rotting rocs." Now, to begin with, the caliph was completely overcome by this very erotic image of having a flask of wine and a loaf of bread and this aroma of rotting rocs. And then suddenly he did one of his double takes and said, "Rotting rocs? Where do you get the stench of rotting rocs?" And within seconds, the whole palace was in an uproar and everybody was down in remote archives, because this poetry was probably written around about 300 or 400 A.D., to find out where the origins of the phrase "stench of rotting rocs" came from. And they went into some of the oldest archives in the palace, and there they discovered that there were ancient manuscripts that described epidemics of roc flu. And during an epidemic of roc flu, hundreds of rocs die in the desert and you get this peculiar aroma or stench.

So you walk into the caliph and make this confident statement about the results of your model, and the caliph instead of patting you on the back and saying, "Well done," says, "Well, that's very interesting, but could you tell me how you modeled roc flu?" And you say, "Roc flu?" And the caliph says, "Yes, don't you know about these epidemics of flu?" And suddenly you see not only your purse disappearing but possibly yourself disappearing as well.

Now, if you had said, if what I've been told is correct, on the basis of best current information, this is what my model suggests, then you might lose your purse of gold, but you should at least manage to maintain your liberty. On the other hand, if you had gone in with a very confident statement about the model, if you had confused the real world and the model world, you could be in grave danger.

What are you going to do? You've suddenly had flu thrown at you. You're going to say, "Caliph, your highness, never, ever has anybody ever mentioned flu before. In fact, when we asked questions about what caused roc mortality, nobody mentioned disease or flu. But if you have information about flu, don't worry, we can put it into our model." And maybe if you're wise you'll say, "We can put it into our model at no extra charge."

So what have they discovered about flu and how are we going to put it into our model? What they have discovered is that only 60 or 70% of rocs survive a flu epidemic. In other words, 30 to 40% of rocs die during an epidemic. They've also discovered that an epidemic never occurs more than once per century. And thirdly, that the probability of a flu epidemic does not depend on whether or not there was an epidemic in the last century. It's a completely independent event, and what they can gather from ancient records is that flu occurs with a

probability of about .25. That is, on average once every 400 years. And if you think about it, an event that occurs once every 400 years is something you could very easily forget about. That's why when you ask people about disease, they told you they knew of no diseases. Last happened - maybe 400, maybe 500, maybe 600 years ago. Nobody remembers it.

Well, the next question is, how are we going to put this into our model? And the first thing we have to figure out is how do we decide in a particular century whether or not there is going to be a flu epidemic? Remember, we've been told it occurs on average once every 400 years. Well, let's go to the spreadsheet and see if there's a way in which we could put flu into the model.

What I've done here is prepared a spreadsheet where I have just put in the year 1000 to 2000, and in the next column I'm just going to put "Flu?" And what I want to do in this column is put in a 0 if there's no flu epidemic that century and put in a 1 if there is a flu epidemic that century.

So, for example, I would start in the year 1100 because I'm saying there was a flu epidemic between the year 1000 and 1100. Suppose I decided there was an epidemic. I could put in a 1. Then I could put in three 0's. Then I could put in a 1. And then I could put in three 0's and then I could put in a 1. And then I could put in a 0.

So that's a potential pattern of epidemics. I've got an epidemic occurring once every 400 years. If I wanted to, I could vary that pattern. I could start with a 0. I could start with two 0's or three 0's. I could use my model to see how the model changed depending on how I varied that pattern.

But let's think about whether this is a good way to do it. If a flu epidemic occurs on average once every 400 years, that means that it's possible that it might not occur at all in a thousand years. Or maybe it could occur every single century in a thousand years. It's a low probability, but it could happen. Notice I'm suddenly starting to use the word '**probability**' a lot.

And probability implies a stochastic model. A stochastic model is one where chance events can occur.

If you think about what we need to tell the caliph about the consequences of having roc flu in the model, we're not going to be able to say this is what's going to happen or is likely to happen to the roc population. We're rather going to be able to say to him this is the probability that you will have a decline in the roc population. Or, this is the probability that the population in a thousand

years will be less than half of the starting population. That is the kind of information that is going to be most useful to the caliph as a decision maker.

How do we get that kind of information out of the model? We get that by building a stochastic model.

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