Bayes for belugas

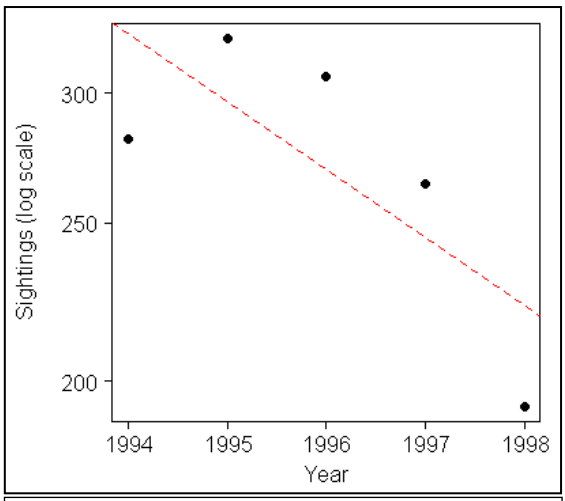
The calculations and graphs for this topic were done in R; the commands are in the script "Bayes_for_Belugas_script.R".

An isolated population of about 350 beluga whales lives in Cook Inlet, Alaska, where they are hunted by native Alaskans. Aerial surveys were carried out from 1994 onwards, and regression analysis was used to try to detect a trend in the population. The data and a Bayesian analysis are given by Wade (2001).

Year:	1994	1995	1996	1997	1998	1999	2000
Sightings:	281	324	307	264	193	217	184

Analysis for 1994-1998

Once the results for 1998 were in, the values for 1994 to 1998 were plotted, as shown in the graph on the right.

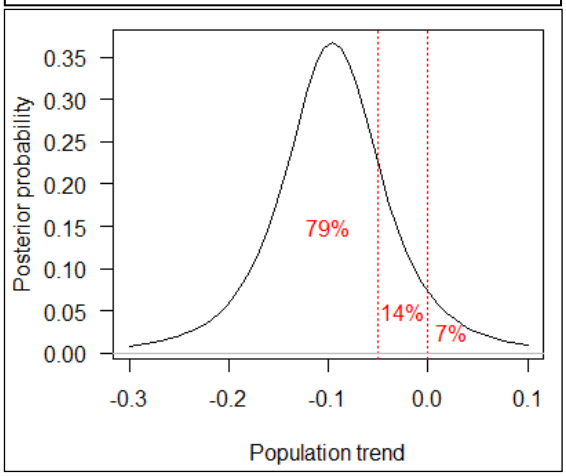


Frequentist analysis

There was a downward trend, estimated to be -9.6% per year. But the 95% confidence interval was very wide, running from -25% to +6%, so the data were consistent with a null hypothesis of no change. From the frequentist point of view, there was no evidence that the beluga whale population was declining.

Bayesian analysis

Using a flat (or uniform or uninformative) prior probability results in a posterior probability which is very close to the likelihood. Assuming a perfectly flat prior, Wade (2001) treated the scaled likelihood curve as the posterior probability. The curve for the 1994-1998 data is shown on the right; the vertical dotted lines correspond to no change (trend = 0) and a decline of 5% per year (trend = -0.05).



On this basis, we can calculate the probability of no decline (trend > 0), a small decline (-0.05 < trend < 0) and a steep decline (trend < -0.05) by calculating the area under the respective parts of the curve.

The probability of a steep decline is 79%, with a probability of only 7% of no decline. On this basis, wildlife managers introduced a moratorium on hunting in 1999.

Results from 1999 and 2000

The results of the frequentist and Bayesian analyses including the results for 1999 and 2000 are summarised in the table on the next page.

Data used:	**1994-1998**	**1994-1999**	**1994-2000**
Estimated trend:	-9.6%	-8.6%	-9.1%
95% confidence interval:	-25 to +6%	-18 to +0.6%	**-15 to -3%**
Posterior probability of no decline:	7%	3%	0.6%
Posterior probability of decline >5%:	79%	83%	93%

Although the estimated population change is a decline of 8% or more from 1998 onwards, it was not until 2000 – with 7 years of data – that strong evidence of a decline according to a frequentist approach emerged. Up to 1999, the data were consistent with a null hypothesis of no change.

Decision analysis

Decision making depends not just on the information on the population trend, but also on the consequences of taking the wrong decision. In a business setting, the losses can often be expressed in terms of money; in conservation, it is usually more tricky, but we can put relative weights of the losses.

For the beluga whales case, we might identify three possible courses of action:

- Relax : do nothing, status quo; appropriate if the population is not declining.
- Act : monitor populations more closely, step up enforcement to stop illegal hunting, inform legal hunters that populations are declining, etc; appropriate if there is a small decline (less than 5%).
- Panic : take extreme action, such as a total moratorium on hunting, closing the area to tourists, etc; appropriate if there is a steep decline (greater than 5%).

The 'loss function' is shown in the table below:

		Actual trend in the population		
		Steep decline	Small decline	No decline
Decision:	Panic	**0**	**1**	**2**
	Act	**1**	**0**	**1**
	Relax	**2**	**1**	**0**

If the population is declining steeply, extreme action ('Panic') is appropriate; if you do nothing ('Relax') the population will soon disappear, scoring a loss of 2; moderate action ('Act') should slow the decline and allow time for further data collection, so the loss is put at 1. On the other hand, if the population is actually not declining, the appropriate action is to do nothing; taking extreme action would be a waste of resources which could be used to protect other endangered species, so in the right-hand column 'Panic' scores a loss of 2.

Now we use the probabilities of the three different events to calculate the expected loss of each course of action. On the basis of the 1994-1998 results, the probabilities are:

- Steep decline: 0.79
- Small decline: 0.14
- No decline: 0.07

For each possible course of action, we multiply the loss by the probability and add up the total, which is the expected loss for that course of action:

		Actual trend in the population			**Expected loss**
		Steep decline	Small decline	No decline	
Decision:	Panic	0 x 0.79	1 x 0.14	2 x 0.07	**0.28**
	Act	1 x 0.79	0 x 0.14	1 x 0.07	**0.86**
	Relax	2 x 0.79	1 x 0.14	0 x 0.07	**1.72**

The minimum loss is associated with the 'Panic' decision, so this was already the best course of action to take once the 1998 survey results were available.

In 1999 and 2000, the probability that the whale population was declining steeply increased steadily, so the expected loss from taking extreme action became smaller and smaller.

For another example of the use of Bayesian analysis and decision rules, this time in the context of the impact of logging on birds and small mammals, see Crome et al (1996).

Conclusions

- Frequentist analysis (such as null hypothesis significance testing) is not an appropriate guide for decision-making by conservation managers.
- Managers should act on the precautionary principle: "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (UNCED, 1992).
- Bayesian posterior probabilities provide the kind of information managers need for decision making and can be incorporated directly in formal decision-making techniques.

References

Crome, F H J; M R Thomas; L A Moore. 1996. A novel Bayesian approach to assessing impacts of rain forest logging. *Ecological Applications* **6**:1104-1123.

United Nations Conference on Environment and Development [UNCED] 1992. *The Rio Declaration*. on line: http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=78&ArticleID=1163

Wade, P R. 2001. The conservation of exploited species in an uncertain world: novel methods and the failure of traditional techniques. Ch 6 in Reynolds, J, G M Mace, K H Redford, and J G Robinson, editors. *Conservation of exploited species*. Cambridge University Press, Cambridge UK.