

Capture-Recapture Estimation and Polar Bears

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Introduction

Most of what we know about polar bears we know from capturing them and then releasing them alive at the site of capture. Capturing bears allows the collection of biological samples (e.g. blood or fat samples) and measurements of physical stature and condition. Perhaps most importantly, capture efforts that are repeated regularly over multi-year periods allow the estimation of vital rates like reproduction and survival and they allow estimation of population size. These parameters have been estimated by what are called capture-recapture analyses, and it is capture-recapture that has provided most of the population assessments we currently have for polar bears worldwide.

So what is capture-recapture? Capture-recapture or mark-recapture is a method, for estimating population size and other parameters, that is based on ratios of marked to unmarked individuals. Perhaps the most famous early application of capture-recapture was estimation, by Pierre Simon Laplace, of the population size of France in 1802 (Cochran, 1978; Stigler, 1986). At that time, live births were recorded for all of France on an annual basis. In the year prior to September 1802, Laplace estimated the number of such births to be approximately $X = 1,000,000$ nation wide. These newly born individuals constituted his *marked* population. Laplace then obtained census and live birth data from several communities scattered across all of France. At that time, census data were not available for most communities, but Laplace chose these communities for his estimate because their “zealous and intelligent mayors” made sure they did have annual census data.

Recognizing temporal variation in annual birth rates, Laplace summed the number of births reported in these sample communities for the three years leading up to the time of his estimate, and divided by three to determine that there were $x = 71,866$ births per year (marked individuals) in those communities. The total number of individuals in these sampled communities was determined by the mayors to be $y = 2,037,615$. The ratio of marked to unmarked was then $p = x/y = 71,866/2,037,615 = 0.0353$. Assuming that the ratio of marked to unmarked in the sample was the same as the ratio of marked to unmarked in the population meant that the total estimated population of France in 1802 was $N = X/p \gg 1,000,000/0.0353 = 28,328,612$.

In its simplest form, a similar estimate for a polar bear population could be derived if you went out one year and captured and marked 100 bears. If the following year you went into the same area and captured another 100 bears and 10 of them were marked, you might conclude, ignoring *details* such as births, deaths, emigration and immigration, that one in ten bears in the population was marked or $p = 0.10$. Because the total sample size was 100 bears the total population size could be estimated as $N = 100/0.10 = 1000$.

So, this is the concept of capture-recapture in its simplest form. Of course, in this simple form, you are limited to a simple estimate of population size. Even more importantly, with capture-recapture as with lots of other things, the devil is in those *details* that were ignored in these examples. In these simple examples, some rather important assumptions were made. For example, the total number of live births in France was treated as a known entity. Of course in fact, it was an estimate. Similarly, the simple polar bear estimate assumed that there was no effect of births or deaths or migration by animals in or out of the area sampled. That is, it was assumed that the total number of marks in the population during the second year was still 100 and that they were all equally available for capture in that second year. These things and many more create complications in capture-recapture estimates. To address these complications, the theories and applications of capture-recapture have moved far beyond the simple models just described.

The devil is in the details:

A major bifurcation in capture-recapture analyses is the division between estimates for populations that are considered open and those that are considered closed. A closed population is one in which the total number of individuals is not changing through births, deaths, immigration or emigration. The first applications of capture-recapture methods were with populations that were assumed to be closed for the period of estimation.

Polar bear populations clearly are not closed. Just as importantly, many other factors can contribute to uncertainties and heterogeneity in the data collected in polar bear studies. For example, polar bears can live 30 years in the wild. Reproduction is protracted and the period of caring for young is long. Thus, at any one time there is a variety of sex and age groups in any population. There is variation among individuals and among sex and age groups in movements and habitat use patterns. Some bears may run when they hear a helicopter engine others may hide. Bears are probably more individualistic than innate in their behaviors. The bottom line is that all individual bears in a population may not be uniformly available for capture. Further, the interest in real populations monitored over time is not just “how many animals are there.” Rather, recognizing populations as dynamic, people also want to know reproduction and survival rates and other characteristics that may indicate population health or status.

Polar bears may be among the most challenging species to which capture-recapture methods are applied, but they are not alone in these challenges. Hence, great advances have been made in methodologies of estimating population parameters from capture-recapture methods.

Conclusion

Most of what we know about polar bear populations is known from capture-recapture kinds of studies. Methods have improved, and we have better estimates of parameters of polar

bear populations than ever before. Many challenges remain, however. For example, polar bears are the most mobile of all non-aquatic mammals and practical study areas often sample only a small portion of the area in which members of each population live. What portion, then, of the total population is represented by derived estimates? And, what about the ability of temporary emigration to bias estimates. Clearly, actual capture probabilities may be very different among individuals and among capture seasons and these differences must be accounted for in models. Further, because capture-recapture estimates of survival are “apparent” survival, an animal that has temporarily left the study area cannot be distinguished from one that has died. Therefore, the polar bears’ great mobility and the researchers’ limited sampling ability are likely to be persistent issues. The polar bears’ multi-year reproductive cycle and the dependence of reproductive success on things that vary greatly among years, like sea ice development and persistence, make assessment of reproductive rates very difficult and add to the length of studies necessary to derive good estimates. Yet, understanding reproduction is an important part of projecting what may happen to polar bear populations in the future. Sample sizes obtainable for most populations are small enough to make the confidence intervals around many of our estimates a matter for concern. Despite these and other issues, however, we largely understand polar bear population dynamics because of capture-recapture efforts.

The body of capture-recapture literature is now so large that this type of estimation method almost comprises its own branch of estimation. Regardless of their complexity, however, all of the approaches described above share a common feature with the simplest applications of over 200 years ago. That is, they are all based at some level upon the ratios of marked to unmarked animals in some kind of sample. Recognition of the “devil” in the details of such estimators has resulted in many novel developments that have resulted in more accurate and precise parameter estimates. Nonetheless, the principles and what the scientists do while out on the sea ice, remain the same, regardless of the complexities of the mathematical models.

References

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