Conservation Biology

Comment

Reevaluating sighting models and moving beyond them to test and contextualize the extinction of the thylacine

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In "Estimating the Extinction Date of the Thylacine with Mixed Certainty Data," we (Carlson et al. 2018*a*) used the sighting record, including controversial post-1936 sightings, to model the probability that the thylacine has been classified accurately as extinct. We found astronomically low odds that the thylacine is extant and argue that a camera-trap search for the species in Cape York, northern Queensland, may be motivated by false hope. In a response to our article, Brook et al. (2018) suggest we were too hasty to dismiss the thylacine as extinct. The crux of their argument is that, although our models imply "all post-1937 thylacine sightings are erroneous [. . .] historical factors and spatiotemporal heterogeneity argue against this conclusion."

We agree with Brook et al. that spatial heterogeneity in sighting rates, and in extinction dates, is a common methodological challenge that must be better addressed. To this end, we recently developed the R package spatExtinct, which interpolates sighting-based extinction date estimators into landscape-level spatiotemporal models that we term "spatial extinction date estimators" (Carlson et al. 2018*b*). Using data that Sleightholme and Campbell (2016) assembled with such a model could help better reconstruct spatiotemporal heterogeneity in the thylacine's extinction on Tasmania, and we are eager to facilitate that analysis. But consensus on the valid use of extinction date estimators in this setting seems a deeper and more persistent issue, as Brook et al. also argue.

On the issue of historical factors, Brook et al. raise the possibility that disincentives for reporting sightings would have increased uncertainty after the thylacine received government protection in 1936, leading to a bias in our models' results. We agree that this likely caused a change in the quality of associated evidence and that there may indeed have been valid sightings after 1936 (even with physical evidence) that were unreported or reported and classified as uncertain in our dataset. Sighting models, like the optimal linear estimator and the Solow and Beet (2014) model, are based on assumptions that search effort never drops to zero prior to extinction (Clements et al. 2013), but given public interest in the thylacine and widespread investment in its rediscovery, we feel safe in that assumption. Furthermore, it seems unlikely that the factors driving reporting hesitancy in the 1930s would still be relevant for the past few decades. If anything, search intensity should be disproportionately high now relative to most of the interval of observation. As the history of putatively extinct species, such as the Ivory-billed Woodpecker (*Campephilus principalis*), and current interest in the thylacine testifies, there are obvious positive incentives for anyone providing definitive proof of the Tasmanian tiger's continued existence.

Brook et al. urge caution "given that for the thylacine (in contrast to most extremely rare or possibly extinct species) apparently plausible sightings have been frequent," but this statement seems to ignore the history

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***Article impact statement**: All available models suggest the thylacine remains extinct until rediscovered; hope remains for other species.*
Paper submitted April 18, 2018; revised manuscript accepted June 29, 2018.

Conservation Biology, Volume 0, No. 0, 1–2

DOI: 10.1111/cobi.13187

of the ivory-billed woodpecker and other extinct species that are similarly targets for cryptozoologists and extinction disputes and the very reason models such as Solow and Beet's (2014) were developed. If anything, the overwhelming frequency of sightings in the absence of definitive proof encourages skepticism about any sighting, even convincing ones. For example, a book chapter Brook et al. cite from *The Tasmanian Tiger: Extinct or Extant* (Mooney 2014) includes the claim: "I know of 3 reports of Thylacine road-kills over many decades." In light of the strong incentive not to report thylacine kills after 1936, it is perhaps even more dubious that these reports would have been made (despite the risks) without any accompanying physical, interrogable evidence.

On that subject, Mooney (2014) deserves special mention with regard to Brook et al.'s claim that "about 100 individuals probably remained in 1933." In Mooney's essay, that number is derived from an approximation based on a "typical" home range size for carnivores, the size of Tasmania (and an unstated assumption that thylacines used the entire island at carrying capacity), and maximum sustainable yield and harvesting values based on plausibility for carnivores. None of these estimates are presented with any empirical support. Rather than rely on what can barely even be called an ad hoc or back-of-the-envelope calculation, scientifically rigorous work is needed for the thylacine (as it is for many recently extinct species) to reconstruct demographic history. Genomic work on the thylacine, published in the last year, offers some important insights into the long-term declines in effective population size and possible extinction drivers, such as El Niño events (Feigin et al. 2018; White et al. 2018). Such research contributes far more lastingly to the scientific literature on the thylacine's extinction and places it more convincingly in the broader context of biodiversity loss in Australia and Tasmania.

Our intention was not to discourage the search for rare, cryptic, or Lazarus taxa, but to help better prioritize it with quantitative tools. The search for the thylacine in Cape York may yet recover plausible photographic evidence of persistence. However, the odds of recovering such evidence are vastly lower than those of recovering blurry and inconclusive photographs, which are likely regardless of the thylacine's true status and will fail to resolve the debate. (A camera-trap photograph of a possible thylacine in Queensland in 2012 is testimony to this fact [Chapple 2014].) While the odds of definitively rediscovering the thylacine through camera trapping are at least as low as the odds the species persists in the first place, the same investigative resources could be directed to other Australian or Tasmanian species that might still be saved from extinction. For example, the Night Parrot (*Pezoporus occidentalis*) was unrecorded between 1912 and 1979, but rare sightings since, including one just this year, offer hope for one of the rarest bird species on Earth. Its distribution, population size and trends, and other aspects of its basic biology are all but unknown, but they are promising targets for future scientific inquiry. There are also many other promising targets, and the decision to prioritize some species over others should be systematic and rigorous. Quantitative tools already exist to help one determine when to stop spending resources on probably extinct species and redirect them toward plausibly salvageable ones (Rout et al. 2010).

Continued enthusiasm for the Tasmanian tiger urges action on common ground in the face of complacency and toward prophylaxis in the face of other looming extinctions. If the thylacine truly exists, it may yet—against all odds—be rediscovered, but other Australian and Tasmanian endemics may still be saved by conservationists' dedicated work. We see no other evidence-based option than to focus on the preventable extinctions that might still be circumvented. In this context, paraphrasing Mooney (2014) slightly, "How wonderful that would be, to just once, (eke out an unlikely victory against) the terrible pandemic of extinction stalking our world."

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