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We need better ways to re-evaluate conservation policies when they're founded on flawed research

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Gopher tortoises (*Gopherus polyphemus*) are not currently protected under the Endangered Species Act for most of their range. Errant model predictions have underestimated threats to gopher tortoise populations. Image credit: Shutterstock/Matthew Yoder.

In November 2023, we discovered what we believed were serious errors in an influential model forecasting trends in the number of gopher tortoises, a declining species threatened by human development and climate change. This model (1, 2) played a key role in the US Fish and Wildlife Service's (USFWS's) decision in 2022 to deny the gopher tortoise federal protection status under the Endangered Species Act across much of its range (3). Once corrected, model predictions changed from a mild population decline to a range-wide collapse. The incident made us realize just how easy it is for flawed models to influence conservation decisions and how hard it is to change course once a policy decision has been made—even after the scientific grounds for the decision begin to fall apart. That needs to change.

Recent reviews suggest that the complex demographic models used to support conservation decisions are highly error-prone (4, 5) and that such errors often pass peer review. Reasons for model failure vary from overly optimistic uncertainty accounting, to improper model specifications that make unreasonable assumptions or fail to account for important processes, to inadvertent coding errors.

The case of the gopher tortoise decision is particularly informative; the flaws in the model are clear, unambiguous, and consequential (6). Nevertheless, our attempts to correct the record and stimulate re-evaluation of policy decisions based on this model have been met with resistance. The ability to self-correct is a core tenet of science, and the apparent inflexibility of the US wildlife conservation apparatus to identify and correct scientific errors will likely undermine its credibility in the long run.

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Errors in Conservation Models

The simulation model used in the gopher tortoise decision belongs to a broader class of methods known as population viability analysis (PVA) (7). These models can integrate a vast trove of information about a species (e.g., demographic, habitat quality, local and global threats) to generate quantitative and seemingly objective results (e.g., predicted future abundance and distribution) that pertain directly to species-level conservation and recovery goals (8, 9). This makes them uniquely well-suited for addressing the Endangered Species Act's requirement to use the "best scientific and commercial data available" (commonly known as the "best available science" mandate; ref. 10). For this reason, researchers and policymakers increasingly turn to complex quantitative analyses such as PVA to support policy decisions involving threatened or endangered species, both in the United States and globally (9, 11, 12).

Some context is important here: The gopher tortoise is a keystone species. Its deep burrows provide shelter to hundreds of native species across a sizable portion of the southeastern United States (13). The tortoises inhabit fire-dependent longleaf pine ecosystems, only a few percent of which remain intact (14). A federal listing could provide critical funding and incentives to conserve the animal's remaining habitat.

> **We suggest several changes that would enable a more resilient, self-correcting, and evidence-based use of quantitative models for supporting conservation decisions.**

In the case of the gopher tortoise PVA, the algorithm for modeling immigration inadvertently introduced an illogical positive feedback that created new "immigrants" within populations in proportion to prior-year population growth. This mistake ultimately inflated abundance forecasts for a substantial subset of populations (6). In addition, we believe the gopher tortoise PVA overestimated the maturation rate of juvenile tortoises, further inflating population growth estimates (6). Although the first error was likely an isolated mistake, incorrect maturation rates are common in matrix population modeling (4). The approach used in the gopher tortoise PVA is attractive due to its simplicity and its inclusion in the authoritative text on this topic (15), despite warnings that the method can severely overestimate population growth for slow-maturing species (4, 15).

More generally, poorly specified models—including logical and coding errors, overparameterization, and improper uncertainty accounting—are prevalent in the wildlife population modeling literature. A recent review found that more than 60% of published population models contained at least one of three common errors (including the maturation rate error mentioned above, in addition to two errors related to the specification of reproductive rates), many of which likely biased or invalidated key findings (4). Another recent meta-analysis uncovered strong evidence for systematic inaccuracies in population models used for managing global fisheries (5).

Applied population ecology faces a crisis of coding and complexity. The models used by applied ecologists often consist of thousands of lines of code. But the ecologists writing the code (present company included) are not properly trained in writing transparent, scalable, and re-usable code, and those reviewing the code lack the time or expertise to provide more than a cursory code review (16).

Despite this high error rate, US conservation agencies do not have an effective way to prevent or correct decisions based on flawed studies. Some fisheries researchers have suggested guards against model misspecification, such as the use of simulation-based goodness-of-fit tests (17) or retrospective analysis of historical subsets of data (18) to evaluate the validity of model predictions, but these have not yet become standard practice in wildlife conservation. Furthermore, once a government agency or other policy-making body incorporates a complex quantitative model into an official policy or procedure, it can be extremely difficult to correct errors or adapt to new information—even if serious issues are discovered that undermine the model's credibility.

Improving Policy Responsiveness

We suggest several changes that would enable a more resilient, self-correcting, and evidence-based use of quantitative models for supporting conservation decisions. We call for rigorous and timely peer evaluation, including expert technical review—we believe the elevated stakes in this context justify peer-review standards that are more rigorous than the current standard practice.

While species status assessments (SSAs) and other official documentation of the scientific rationale for conservation decisions are routinely peer-reviewed prior to policy implementation, the methods and algorithms for running these models should undergo a systematic technical review by a panel of independent modeling experts—especially if a policy decision relies on a complex quantitative model. With full access to data and code, technical experts could ensure replicability of results (19); run a battery of tests for coding errors, logical inconsistencies, and improper uncertainty propagation; and assess overall compliance with stated assumptions. This review would complement, rather than replace, standard peer review, which often relies on species expertise rather than technical expertise.

Because technical review can be extremely time-consuming, conservation agencies should identify a mechanism for compensating reviewers and allow sufficient time for review, and technical reviewers should be instructed to only scrutinize those subsections related to their area of expertise. All scientific documents, code, and data (possibly anonymized to protect sensitive species) used to support conservation decisions, as well as peer-review reports, should be made available to the public well in advance of any policy decision. And so should peer-reviewed publications—influential population models are often published in the scientific literature after they have impacted official policy (e.g., ref. 20, which influenced horseshoe crab harvest policy in Delaware Bay, with implications for a federally threatened shorebird). Timely and transparent transmission of information would enable interested parties to participate in model evaluation and potentially even offer alternative hypotheses about the target natural system—after all, simultaneous testing of multiple alternative models is a cornerstone of scientific natural resource management (21) and of scientific progress more broadly.

We also would like to see efficient post hoc mechanisms for changing course. The legal process can be costly and time-consuming, and legal technicalities can obscure scientific evidence. For example, we provided a written legal declaration as part of an ongoing lawsuit contesting the USFWS's 2022 gopher tortoise listing decision. This document, in which we clarified the issues with the PVA model, was found to be inadmissible due to a legal technicality. Therefore, the court must make its ruling in the absence of credible evidence of serious errors in the scientific rationale for the decision in question—underscoring the pitfalls in relying on the legal system to ensure that policy decisions remain grounded in sound science. Ideally, agencies would be incentivized to correct issues proactively.

To this end, USFWS and other natural resources protection agencies should have a functional mechanism for considering and reviewing legitimate scientific criticism, even after a policy has been finalized. Such a mechanism would enable individuals and organizations to work constructively with policymakers, rather than seeking changes through slow and often rancorous legal battles. The International Union for the Conservation of Nature petitions process (22) provides a compelling model here. Although there is a final authority—an independent panel—to settle disputes about species listed on the Red List, disagreements are strongly encouraged to be resolved informally.

We would like to see fewer barriers to amending the published record for problematic models in peer-reviewed journals. Publishers (even smaller "niche" publications) should have a clear, streamlined, and cost-free policy for handling errors that outside researchers discover after publication. Publishers must also unambiguously notify readers of credible errors discovered in previously published work, especially if major results are called into question. In our attempt to correct the published record regarding the gopher tortoise PVA, we were surprised to find that no such policies were in place, despite the journal being part of a large academic publishing network.

Finally, as with any field of science, retraction is warranted when modeling errors such as these severely overstate population resilience or otherwise invalidate key conclusions (see guidelines in ref. 23). And yet, it's very rare to see a retraction of a published wildlife population model, despite a high prevalence of errors in the literature (4). We suspect that cultural or institutional norms, coupled with the stigma of retraction (24), may steer authors and publishers away from retraction, even when it is appropriate. In the case of policy-relevant research, retraction would provide the strongest possible signal to policymakers that the work should no longer be used as the scientific basis for policy or management actions. Authors who recommend retraction of their work due to hidden modeling errors should be celebrated, rather than vilified. Finally, retraction of a published work (or major corrections) should trigger immediate re-evaluation of any policies influenced downstream.

While it is always hard to generalize from a specific case, we hope our experiences help pave the way for a more sensible implementation of the concept of "best available science" in wildlife conservation and management. As for the gopher tortoise, we hope that science will prevail, despite the formidable obstacles that continue to stand in the way.

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