Erroneous assumptions by Crabtree et al. yield misleading and invalid conclusions

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Crabtree et al. recently posted a preprint of an article online (i.e., prior to peer review) to make an argument that Montana Fish, Wildlife and Parks (MFWP) is overestimating wolf abundance using the state's wolf abundance estimator, iPOM (the integrated patch occupancy model, Sells et al. 2022). However, their analysis and the resulting misleading findings are based on erroneous interpretations of iPOM and how the estimator is used. We agree fundamentally with their assertion that scientific peer review is needed to help ensure rigor in monitoring program design, and this is why we have been using the scientific peer review process during the development of the iPOM methodology over the last 15 years. We believe that peer review will address the severe misinterpretations in the Crabtree et al. analysis prior to being published, and if it is published in the peer-reviewed literature we will respond in detail in that forum. However, as the article has already been posted online ahead of the wolf plan comment deadline and distributed to the press, we briefly address their key arguments below.

iPOM estimates abundance of wolves in Montana using 3 submodels: an occupancy model, a territory size model, and a group size model. The occupancy model first estimates wolf distribution in Montana, based on environmental covariates and wolf observations within a statewide observation grid that consists of 600 km^2 grid cells. This model also explicitly accounts for errors in the process of observing wolves, including failing to detect wolves when they are actually present and false identification and reporting of wolves when they were not present. The territory model estimates territory sizes. Together, these models estimate the number of packs, based on how many territories could occur within the occupied area (essentially, area occupied / territory size), correcting for the various sizes of territories in occupied areas. The group size model then helps estimate the number of pack-living wolves (# territories x pack size). Total wolf abundance is calculated as the number of pack-living wolves multiplied by 1.125 to also account for lone wolves; full details are in Sells et al. (2022).

Crabtree et al. focus primarily on the occupancy and territory model components and conclude that iPOM overestimates wolf abundance by 2.5 times the true abundance. They arrive at this flawed interpretation based on a major assumption: *the entirety* of any 600 km^2 grid cell with wolf observations is included in the sum of area occupied. To illustrate the effect of Crabtree et al.'s interpretation, we used their methods to calculate wolf abundance. Summing the area of any grid cell with wolf detections results in an estimated area occupied by wolves in Montana of 123,688 km^2 – 179,565 km^2, which is 1.74 - 3.38 times the area iPOM estimated was occupied each year. In fact, no grid cells in iPOM have an occupancy = 1 (average occupancy = 0.20; means ranged 0.13 – 0.23 per year) because habitat features and survey effort in each grid cell influence the probability of wolf occupancy. This drastically reduces in iPOM the total area occupied and the resulting estimates of # of packs and wolves compared to what would be estimated using the Crabtree et al. method. (E.g., at the peak population size in 2011, Crabtree et al.'s methods[i] would estimate 402 packs and 2,310 wolves, whereas iPOM estimated 188 packs and 1,259 wolves. In 2022, their methods estimate 302 packs and 1,738 wolves, whereas iPOM estimated 181 packs and 1,087 wolves.)

If Crabtree et al.'s conclusion were true that iPOM inflates the true abundance estimate for wolves by a factor of 2.5, the actual estimates of wolf abundance would be well below the minimum counts of

verified packs and wolves known to exist in Montana each year (Fig. 1). It is important to note that minimum counts by MFWP field staff represent the number of known wolves from field efforts to estimate pack and territory size and to collar packs in proximity to livestock (per state law). They do not represent a concerted effort to enumerate the total number of wolves, so we are absolutely confident that more wolves exist on the ground than are represented by these counts.
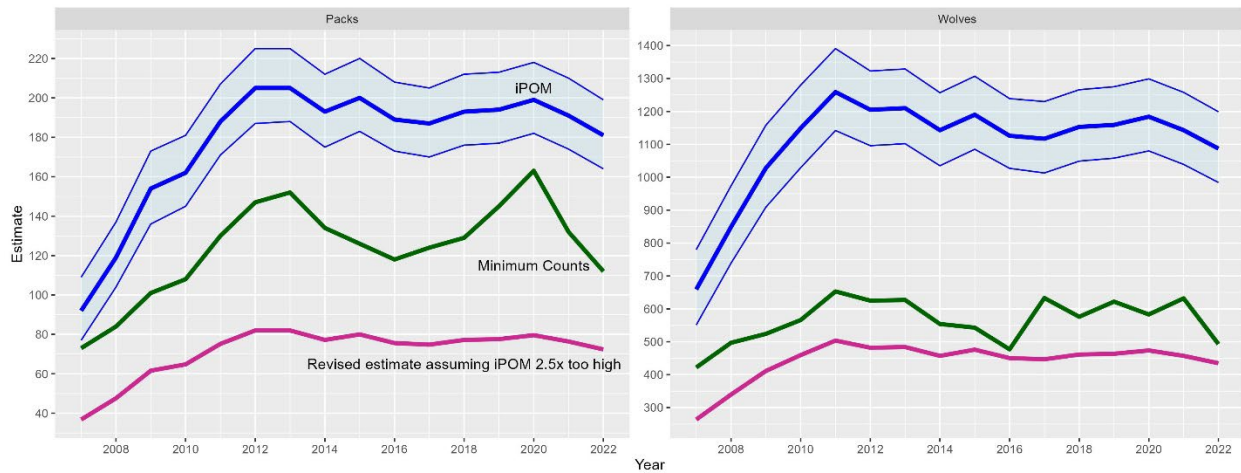
Figure 1. If iPOM overestimates true abundance by a factor of 2.5, revised abundance estimates would be as shown in pink. However, these fall well below MFWP's survey results for minimum numbers of packs and wolves verified each year (green).

There are myriad other unsupported assumptions and flawed interpretations of iPOM in Crabtree et al.'s preprint (e.g., how the territory model is used, and the assertion that iPOM uses an ad hoc correction factor for territory overlap). Under the normal scientific process of peer review (through which 5 publications of iPOM and its components have passed[ii]), if Crabtree et al.'s article was accepted for publication, these misinterpretations would be identified and corrected prior to public dissemination, and we would have the opportunity to respond via peer-reviewed rebuttal. Technicalities of complex abundance estimators, their properties, and their accuracy are best discussed under this process, where errors can be preempted or debated with rigorous oversight by experts. Bypassing this route can lead to misinterpretation, misunderstanding, and misleading inferences that confuse rather than contribute to effective public debate. We look forward to a scientific discussion of iPOM with Crabtree et al. conducted under the scrutiny of scientific peer review. Such discussion is useful for ensuring both the rigor of science and effectiveness of management based on that science. Until that occurs, however, the methods and conclusions of Crabtree et al. must be considered preliminary and weakly supported at best. The example we present here (and others we will present in the peer-reviewed literature) further suggests flaws in the approach taken by Crabtree et al. that should strongly call into question the merits of their contribution to estimating wolf abundance in Montana.

Citations

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[i] Crabtree et al. illustrate their argument with an assumed territory size of 447 km^2, pack size of 5, and lone wolf adjustment of 1.15. To illustrate the effects of Crabtree et al.'s calculations in these examples, we thus estimated the number of packs as area occupied / 447 km^2, and the number of wolves as # of packs x 5 x 1.15.

[ii] Before iPOM's development in recent years, there were numerous prior publications supporting the occupancy model, which has been used in Montana to estimate wolf abundance since 2013 and to report abundance estimates back to 2007.