EVALUATING THE SCIENTIFIC SOUNDNESS OF PLANS FOR HARVESTING WOLVES TO MANAGE DEPREDATIONS IN MICHIGAN

Report Number 2013-3
August 2013

Prepared by:

JOHN A. VUCETICH, Michigan Technological University, School of Forest Resources and Environmental Sciences, Houghton, MI 49931, USA

JEREMY T. BRUSKOTTER, The Ohio State University, The School of Environment and Natural Resources, Columbus, OH, 43210 USA

ROLF O. PETERSON, Michigan Technological University, School of Forest Resources and Environmental Sciences, Houghton, MI 49931, USA

ADRIAN TREVES, University of Wisconsin-Madison, Nelson Institute for Environmental Studies, Madison, WI 53706, USA

TIMOTHY VAN DEELEN, University of Wisconsin-Madison, Department of Forest and Wildlife Ecology, Madison, WI 53706, USA

ARI M. CORNMAN, Little River Band of Ottawa Indians, Natural Resources Department, 375 River Street, Manistee, MI 49660, USA

Suggested Citation:
Vucetich, J. A., J. T. Bruskotter, R. O. Peterson, A. Treves, T. Van Deelen, and A. M. Cornman. 2013. Evaluating the scientific soundness of plans for harvesting wolves to manage depredations in Michigan. Little River Band of Ottawa Indians Natural Resources Report No. 2013-3.

Summary

1) In 2013, the Michigan Department of Natural Resources (MI-DNR) began implementing a plan to harvest wolves. The stated purpose of the harvest is to reduce threats to livestock and human safety. While the MI-DNR has indicated that its plan is based on sound science, they have not presented any scientific evaluation of its plan. Moreover, we are unaware of any scientific evaluation of the prospects of success for the plan. Providing for sound science is required by Michigan law. Here, we provide a scientific evaluation of the prospects for successfully managing depredations in Michigan through the use of wolf harvesting.

2) This analysis indicates that realizing anything but trivial declines in depredations requires killing more wolves than would be appropriate. For example, reducing the expected number of farms affected by depredations each year by just a single farm, from 17.7 to 16.8, would require reducing wolf abundance, across Upper Michigan by ~20%, which would require harvesting approximately one out of every three wolves. That number of harvested wolves would be in addition to the wolves that will also be killed by poachers.. Moreover, the spatial scale at which the MI-DNR plans to implement harvest will cause harvesting to be less efficient than suggested by statistics such as that reported in the previous statement.

3) Another anticipated result of the management plan is that harvesting wolves may alter wolves' behavior in a manner that would reduce livestock depredations. The available evidence does not support this expectation.

4) The ecological relationships associated with using harvest to manage depredations are characterized by considerable statistical and scientific uncertainty. In such circumstances, a scientifically sound management plan *must* account for the principles of adaptive management. Those principles include transparently: (i) specifying the goals of the harvest, (ii) using available data to assess the likelihood of realizing the specified goals given the planned management, (iii) specifying a plan to evaluate whether the actions were successful in realizing the goals, and (iv) specifying how actions are expected to be adjusted should the goal not be realized. The plan does not contain *any* of these basic elements. Analyses presented here strongly suggest that if the MI-DNR were to state an adequately specific goal, that such a goal would be extremely unlikely to be met through the harvest of wolves. These circumstances represent clear, unequivocal evidence that plans to harvest wolves in Michigan for the purpose of managing depredation are scientifically unsound. Fortunately, other effective means of managing depredations exist.

Background

One of the two reasons offered by the Michigan Department of Natural Resources (MI-DNR) for harvesting wolves is to reduce the number of depredations. The MI-DNR describes its plan for achieving this goal as being geographically targeted. In particular, the MI-DNR has identified three wolf management units (WMU) for 2013 where it will focus wolf harvesting (Fig. 1). For example, in WMU B 80 livestock on 11 farms were reported to have been killed by wolves between January 2010 and April 2013. In response, the MI-DNR plans to harvest 19 wolves in WMU B during Fall of 2013. They estimate that number of wolves to be harvested represents about 20% of the wolves living in WMU B. The intention is to reduce the number of depredations in WMU B. The MI-DNR has plans to harvest wolves at similar rates in WMU C to reduce depredations and in WMU A to reduce the number of humans making nuisance complaints about wolves.

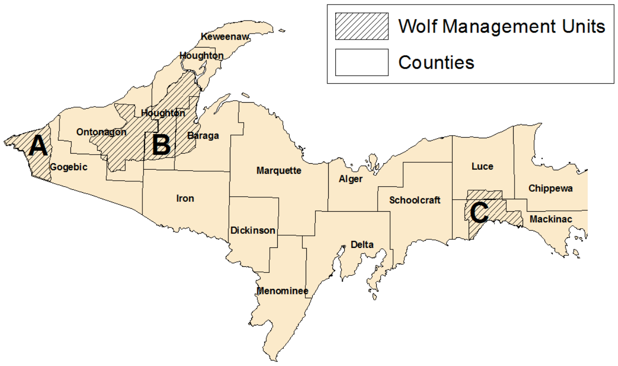

Fig. 1. Wolf Management Units for 2013.

The MI-DNR does not expect the total number of wolves harvested to affect the overall abundance of wolves in Upper Michigan, but it may reduce wolf abundance in the particular WMUs where wolves are hunted. In particular, they expect that a 20% harvest rate added to an estimated 15% rate of background mortality due to other human causes (e.g., poaching, lethal control, car collisions) would reduce abundance in the WMU by 25%. The MI-DNR also anticipates that harvesting wolves may alter the behavior of wolves living near livestock in a way that would reduce the number of depredations. Finally, the MI-DNR has implied that it will adjust rates of harvest up or down in each WMU over time in response to recent levels of depredation and in response to the perceived effect of previous harvests.

The MI-DNR also stated that plans to harvest wolves are based on sound science. However, they do not cite what science they are referring to, and we are unaware of any science that supports critical elements of the plan. This document is a scientific analysis of the appropriateness of using a public harvest to manage depredations in Michigan.

Wolf abundance and depredation

The primary basis for the MI-DNR's expectation that wolf harvesting would reduce depredations appears to be the statistical tendency for the number of depredations to increase with wolf abundance. In particular, for the period 1996-2012, the statistical association between wolf abundance and number of depredations is highly significant ($p=6.6\cdot10^{-5}$; Fig. 1). Moreover, the proportion of variation in depredations that can be accounted for by wolf abundance is relatively high (i.e., $R^2 = 0.67$). Using Figure 1 to justify wolf harvesting as a means of controlling depredations requires assuming that the relationship is largely causal and not merely correlative. Sound-scientific reasoning indicates how that assumption is not fully appropriate and may simply be inadequate

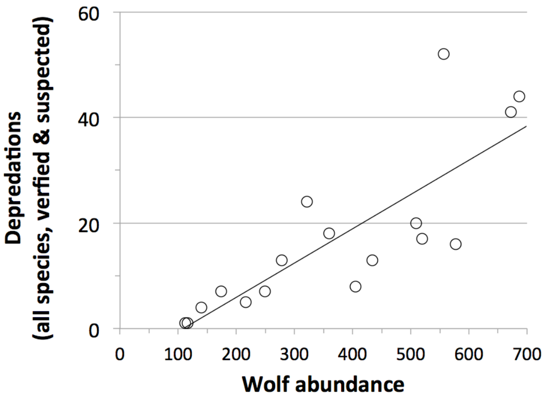

Fig. 2. Relationship between estimated wolf abundance and depredations in Upper Michigan, 1996-2012.

(see below). Nevertheless, even if one were to fully grant the assumption, the relationship in Figure 1 is still an inappropriate basis for thinking that wolf harvest is a scientifically-sound means of managing depredation. The problem with the relationship in Figure 1 is revealed by a more thorough analysis of the statistical uncertainty characterizing that relationship.

To provide context for such an assessment, consider that 41 depredations (all species, verified and suspected) were reported in 2012, a year during which there were also approximately 675 wolves. The simple linear regression line in Figure 1 indicates that the *expected* number of depredations, given this wolf abundance, is 36.8.

The foundation of this analysis is appreciated by observing that the realized number of depredations in a particular year (represented by the circles in Figure 1) typically differs, and often by a great amount, from the expected number of depredations in a particular year (represented by the regression line). For this reason, the regression line is, by itself, an inadequate indication of the relationship between wolf abundance and the actual, observed number of depredations. Critical insight rises from confidence intervals in the number of depredations, for any given level of wolf abundance. For example, when wolf abundance is 675, then the 80% confidence intervals for the number of depredation is [23.3, 50.3]. The approximate meaning[1] of this statistic is: When there are 675 wolves, one can be 80% confident that the realized number of depredations will be somewhere between 23.3 and 50.3. Put another way, when there are 675 wolves, there are as likely to be 23.3 or fewer depredation as there are to be 50.3 or more depredations. From a management perspective, this is a remarkably wide range of depredations.

Suppose, simply for the sake of illustration, that a planned harvest would reduce overall wolf abundance by 10%, say from 675 to 608 wolves. The regression line in Figure 1 indicates that the expected number of depredations would decline from 36.8 to 32.4 depredations. However, the statistical uncertainty and confidence intervals that correspond to this relationship are considerable. Consequently, there is a considerable chance that depredations would increase, just by luck, with a 10% decrease in wolf abundance (Table 1). Table 1 shows what can be expected, if Figure 1 depicts a purely causal relationship, for declines in depredation, given various reductions in wolf abundance.

That table indicates, for example, that reducing wolf abundance by 20% results in only a 56% chance of realizing a decline of 7 (or more) depredations each year[2]. That

---

[1] The technical interpretation of a confidence interval is more nuanced than what is stated above. Nevertheless, it captures the practical meaning of those confidence intervals. Furthermore, by the

[2] See *Adaptive Management and Success Criteria* (below) for a discussion of what would count as a meaningful decline in depredations.

is, the probability of realizing a reduction in depredations by reducing wolf abundance by 20% is essentially equivalent a coin toss (i.e., 0.50). For context, there is also a coin toss's chance (50%) of realizing a reduction in depredations even if no wolves are harvested.

TABLE 1. EFFECT OF REDUCING WOLF ABUNDANCE ON THE NUMBER OF DEPREDATIONS.

Reduction in wolf abundance	**Expected number of depredations**	**80% Confidence Interval**	**Probability of realizing an *increased* number of depredations, in spite of reduced wolf abundance**	**Probability of realizing a *decrease* in depredations from 36.7 to less than or equal to 30**
0% (675 wolves)	36.7	[23.3, 50.3]	0.50	0.31
10% (608 wolves)	32.4	[19.3, 45.5]	0.37	0.43
20% (540 wolves)	28.0	[15.2, 40.9]	0.26	0.56
30% (472 wolves)	23.6	[11.0, 36.3]	0.16	0.69
40% (405 wolves)	19.2	[6.7, 31.8]	0.09	0.79

The calculations in Table 1 assume that the variance in number of depredations is constant with respect to wolf abundance. Figure 1 suggests otherwise. Variation in depredations appears to increase considerably with increased in wolf abundance. Accounting for that increase would almost certainly add to the uncertainty that is portrayed in Table 1.

If managing losses due to depredation is important, paying for the lost economic value of seven head of cattle (on the order of $2,500, total[3]) would be more reliable and effective than harvesting wolves. Regardless, the available evidence clearly indicates that reducing wolf abundance to manage the number of depredations would be remarkably inefficient and ineffective.

This conclusion is also supported by analyses (not shown) that focus on cattle only and dogs only, rather than treating all depredations together (as depicted in Figure 2). The analysis represented by Figure 2 and Table 1 also estimated wolf abundance in 2012 by interpolation of estimates for 2011 and 2013. If data from 2012 is omitted, the relationship between abundance and depredation is characterized by *more* statistical uncertainty than indicated by Table 1.

Forecasting ecological events

One aspect of these results deserves explanation. In particular, how can the statistical relationship between wolf abundance and depredations be so highly significant and with a relatively large R^2 ($p = 6.6 \cdot 10^{-5}$, $R^2 = 0.67$; Fig. 2); yet, at the same time, the prospects for realizing reductions in depredations are so poor? The explanation for this circumstance follows:

First, statistical significance is not, in general, an indication for the ability to make adequately precise predictions about future events. Statistical significance is *not* an indication that reducing, even substantially, the predictor variable (wolf abundance)

---

[3] This value is estimated from Table 5 of Roell et al. (2010).

will result in realizing an adequate reduction or any reduction in the response variable (depredations). Realizing that kind of reduction requires a steeper slope *and* higher R^2 than were observed in Figure 1, provided, of course, that the relationship in Figure 1 is purely causal.

Also, if the R^2 observed in Figure 1 seems large, that is only in comparison to informal standards for evaluating whether one ecological parameter has in the past had some connection to another ecological parameter. The standard for concluding that one ecological variable (depredations) can be adequately managed or controlled by manipulating another variable (wolf abundance) is different and represented by the calculations in Table 1. By those standards, the R^2 observed in Figure 1 is not large.[4]

In other words, the observed R^2 is large compared to many ecological relationships that have been observed in nature. However, nature is impressively stochastic and ecological phenomena are the result of many factors operating simultaneously. As a result, R^2 values of the size observed in Figure 1 satisfy the intellectual curiosity of ecologists aiming to understand whether two ecological variables have, in the past, been connected in some way. Nevertheless, the standards for developing a *general understanding of past events* are not the same as the standards for making adequate *predictions of the future*. Because ecologists spend most of their time understanding the past, rather than making formal predictions of the future, their intuition for the latter tends not to be as reliable. This is why the formal calculations in Table 1, which represent the standards for making formal predictions, are so important.

Wolf abundance and harvest rate

Attempting to manage depredations by harvesting wolves is a two-step process and involves two statistical relationships (Fig. 3). The second relationship is described in

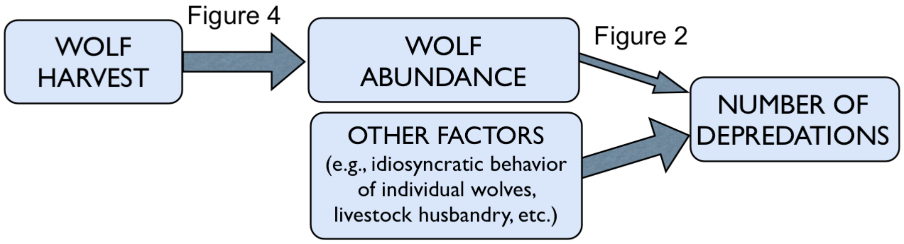

Fig. 3. The statistical relationship between wolf harvesting and number of depredations is comprised of two sequential statistical relationships, each characterized by considerable statistical uncertainty. The first is the relationship between harvest rate and wolf abundance (see Figure 4). The second relationship is between wolf abundance and number of depredations (see Figure 2 and Table 1). The potential for harvest to reduce depredations by altering the behavior of wolves is discussed below, in Wolf Harvesting and Wolf Behavior. *This conceptual model also highlights that the number of depredations is influenced by more than wolf abundance, and there is no scientific evidence to suggest that abundance is the most important, or even an important, causal determinant for the number of depredations (see for example, Treves et al. 2011).*

---

[4] For additional context, the value of R^2 = 0.67, reported in Figure 2, means that a third of the variation in depredations is not accounted for by wolf abundance.

the previous section. Further uncertainty for the effect that harvesting wolves would have on depredations is revealed by considering that first ecological relationship, which is the relationship between harvest rate and wolf abundance (Fig. 4).

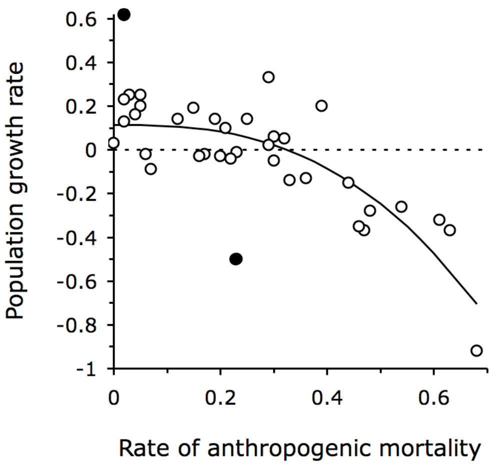

Fig. 4. Relationship between rate of anthropogenic mortality and population growth rate for populations of wolves living at various sites throughout North America. The filled circles are outliers. The curved line is the best fitting non-linear model (y=0.114 – 2.284x$^{2.658}$*; R*^{2}*=0.71; p<0.01). Data are from Adams et al. (2008). Anthropogenic mortality includes harvest, poaching, lethal control, and car collisions.*

The relationship in Figure 4 can be used as a basis for predicting how various rates of harvest are expected to affect wolf abundance. Suppose the intention is to reduce abundance by 20% (see the scenario implied by Table 1). That reduction in abundance corresponds to a growth rate of –0.20 (y-axis of Figure 4). An expected growth rate of –0.20 corresponds to killing 47% of the wolves in an area (see Appendix B).

Moreover, those statistics represent an incomplete perspective because they do not account for the statistical uncertainty characterizing the relationship between mortality and population growth rate in Figure 4. Because of this uncertainty, killing 47% of the wolves in an area is also associated with a twenty percent chance of reducing wolf abundance by *more* than 35%, and a twenty percent chance of reducing wolves by less than 6%. In other words, the *best* chances for realizing the desired outcome would still be accompanied by a forty percent chance of realizing an undesirable outcome (i.e., either reducing wolves too little to make a difference, or reducing them too much). The uncertainties described above would be amplified by limited knowledge of how rates of poaching fluctuate over time and in response to the opportunity for citizens to harvest wolves legally.

The MI-DNR believes it is taking a conservative approach to this statistical uncertainty. In particular, they are planning for the rate of anthropogenic mortality in the WMUs to be 0.20 (harvest rate) plus 0.15 (other sources of anthropogenic mortality, such as poaching), which would yield a total rate of anthropogenic mortality of 0.35. That rate of mortality corresponds to an expected population decline of 2.6%. These calculations differ considerably from the expectations reported by the MI-DNR (i.e., they expect a 25% decline in abundance within the WMUs). That difference is of significant concern. Nevertheless, it is not possible to evaluate why the MI-DNR expectations differ because they have not presented any scientific evidence (i.e., statistical analysis) to support their expectations.

This approach is not conservative by the standards to which management should be judged, because killing wolves at that rate has essentially no chance of reducing abundance enough to have any effect on depredations. The scientific soundness of management depends on the likelihood of realizing the management goals in response to the planned management actions.

The inherent problem with using wolf harvesting as a tool to manage depredations is that too many wolves have to be harvested to realize anything but a trivial decline in depredations. Planning to kill too few wolves to have any appreciable effect on depredation is not a conservative plan; it is a planned failure. The circumstances would be different if the cost of the planned management actions were negligible, but they are not. Rather, the costs of the planned management actions are considerable. That is, considerable cost is incurred for planning to kill dozens of sentient creatures with little or no hope of realizing the purpose for that killing[5].

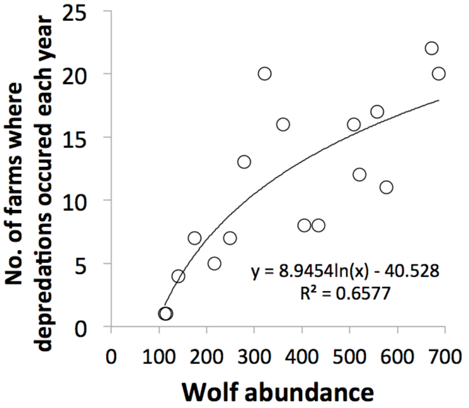

Fig. 5. Relationship between wolf abundance and number of farms affected by depredations in Upper Michigan, 1996-2012. These include depredations of all species, verified and suspected.

Number of affected farms

Concern for the number of farms affected by depredations each year is similar in importance to concern for the total number of depredations occurring each year. Moreover, the relationship between wolf abundance and the number of affected farms is statistically significant ($p<0.01$), and wolf abundance explains a relatively large portion of the variance in the number of affected farms ($R^2=0.66$; Fig. 5).

However, reducing wolf abundance by 10% from 675 to 608 reduces the expected number of affected farms by just a single farm, from 17.7 to 16.8. Reducing the expected number of affected farms by four (to 13.2) would require reducing wolf abundance by 40%, from 675 to 405 wolves.

The statistics in the preceding paragraph focus on expected reductions in the number of affected farms, and do not account for the difference between expected and realized outcomes. Because the confidence intervals for the number of affected farms is relatively large[6], one can expect considerable differences between expected and realized outcomes. For example, after reducing wolf abundance by twenty percent there is a 39% chance that the realized number of affected farms would actually increase[7]. The available evidence clearly indicates that using wolf harvest as a tool to manage the number of affected farms would be remarkably inefficient and ineffective.

---

[5] That wildlife managers be concerned with this cost is not a standard that we impose on wildlife management; it is a standard imposed by wildlife managers on themselves. For example one of the seven principles of the North American model of Wildlife Conservation is that wildlife not be killed for frivolous reasons. Hunting wildlife without realizing the intended purpose of that killing is to kill for a frivolous reason.

[6] The 80% confidence intervals for the number of affected farms, given 675 wolves is [12.0, 23.5].

[7] The result is based on calculations like those depicted in Table 1.

Spatial scale

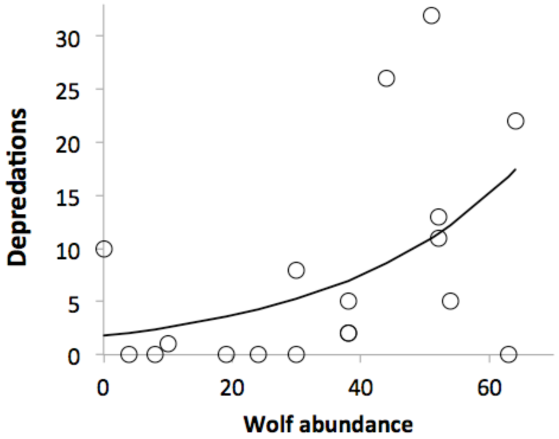

Fig. 6. Relationship between wolf abundance and number of depredations within wolf management unit B (see Figure 1), 1995-2012. Depredations include all species, verified and suspected.

The analyses associated with Figures 2 and 5 are based on data gathered at a relatively large spatial scale (i.e., all of upper Michigan). By contrast, the MI-DNR plans to manage the depredation through wolf harvesting at a smaller spatial scale. Nevertheless, the analyses presented here, representing larger spatial scales, are relevant for two reasons.

First, the larger spatial scale highlights the magnitude of reduction in depredation to be expected if the MI-DNR were to apply management at the large scale. However, this is not their intention. Consequently, the expected magnitude of the reductions in depredations will be even smaller than what is reported here.

Second, for the application of harvesting at a smaller geographic scales to be sensible, the relationship between wolf abundance and the number of depredations would have to be considerably stronger and more precise than what is observed at the larger spatial scale. This, however, appears not to be the case. For example, the relationship between wolf abundance and number of depredations within WMU B (Fig. 1) is weaker than what is observed at the larger spatial scale (Fig. 6). In particular, the Poisson regression model depicted in Figure 6 accounts for only 21% of the observed variation in depredations, less than a third of the variation predicted at the larger spatial scale of the entire Upper Peninsula[8]. Consequently the results presented above, in *Wolf abundance and depredation*, are overly optimistic.

The reason for the weaker relationship at the smaller spatial scale is that the number of depredations is a highly stochastic event that depends on many variables. At smaller spatial scales the idiosyncratic nature of depredations dominates. Only at larger spatial scales does one see the kind of relationships depicted in Figures 2 and 5. This idiosyncratic nature is why depredations are not well managed by a crude tool such as wolf harvesting, even when applied at relatively small spatial scales. Rather, depredations in a place like Michigan, where depredation events are relatively uncommon (compared to western states), are effectively managed only through more targeted methods like those which have been employed by the MI-DNR in the past.

---

[8] In particular, the relationship between abundance and depredations across the Upper Peninsula is characterized by an R^2 of 0.67 (see Figure 2). That statistic indicates that abundance accounts for 67% of the variation in depredations (at the scale of the Upper Peninsula). In the context of Poisson regression, the comparable statistic is not R^2, but is called, a prediction error. The prediction error for the model depicted in Fig. 6 is 0.21. In other words, the relationship between abundance and depredation at the scale of a WMU is characterized by much more statistical uncertainty than what is observed at the larger spatial scale of the entire Upper Peninsula.

Another concern about planning to focus harvesting within particular WMUs is that some portion of the harvest will, nevertheless, be comprised of wolves that are reported to have been killed within a WMU, but are actually killed outside the WMU. That expectation means that the harvest will be less geographically focused than intended. This circumstance should also be expected in spite of diligent law enforcement.

Wolf harvesting and wolf behavior

An advocate for managing depredations through wolf harvesting might insist that doing so is sensible not because of the relationship between wolf abundance and depredations, but instead because of the expected effect of harvest on the behavior of surviving wolves. That is, some believe that harvesting wolves should be expected to change their behavior in a way that would reduce depredations.

We searched the scientific literature and spoke with several knowledgeable colleagues and were unable to find any scientific evidence to support this claim. For example, we are unaware of any wildlife management agency that implemented and evaluated a harvest primarily for the purpose of making a predator behaviorally averse to depredation. If the MI-DNR has scientific evidence to suggest otherwise, they should share that knowledge. To date, they have not.

Moreover, existing knowledge of wolf behavior provides several reasons to believe that the planned harvest will not alter the behavior of wolves in a way that would reduce depredations.

First, no evidence exists to suggest that wolves have, in general, the capacity to know the difference between poaching, lethal control, or regulated harvest. And, humans have already been killing wolves in Upper Michigan on a regular basis for several wolf generations. There is no need to conduct a management experiment to see if killing wolves will affect their behavior. We have already been conducting that experiment and have observed its effects. Any behavioral modification attributable to the lethal removal of wolves are already be in place.

Second, there is a mismatch between the time of year when harvesting would occur and the time of year when most depredations occur (Figure 7). The cognitive abilities of a wolf include the capacity to understand when and where threats to their lives occur. There is little doubt that wolves are intelligent enough to quickly learn that a risk being harvested in November and December is not a threat to their killing livestock in spring and summer, which is the time when most depredations occur[9].

Third, a likely effect of harvesting wolves within any WMU is to increase the number of wolves immigrating into the WMU. These immigrating wolves that have not been acculturated (aversively conditioned) to living in areas with livestock are more

---

[9] Every hunter who has scouted the behavior of a deer prior to hunting season is impressed by their capacity to understand where and when their lives are at risk of being killed by a human. If deer are capable of such an ability, certainly wolves are too. Extensive research indicates that carnivores, including wolves, tend to adjust their behaviors match the time and place where human threat exists (van Schaik and Griffiths 1996, Gibeau et al. 2002, Beckmann and Berger 2003, Bunnefeld et al. 2006, Chavez and Gese 2006, Larrucea et al. 2007, Hebblewhite and Merrill 2008, Sweanor et al. 2008).

likely to kill livestock. For this reason, harvesting could exacerbate losses to livestock (see also Bangs and Shivik 2001; Treves and Karanth 2003; Treves and Naughton-Treves 2005). The same conclusions results from considering other expected effects of harvest on wolf populations (i.e., Brainerd et al. 2008; Wallach et al. 2009; Rutledge et al. 2010).

According to a July 2013 report in the Minneapolis Star Tribune, Dan Stark of the Minnesota DNR believes that existing evidence indicates that declines in complaints about wolf depredation in Minnesota during the previous year are "likely explained" by the targeted removal of wolves (by state and federal trappers) that had been living near farms and threatening livestock, and not the wolf harvest (Smith 2013). Other forthcoming analyses also suggest that the number of depredations may have increased in response to harvesting (Kunkel 2013, see also Musiani 2013).

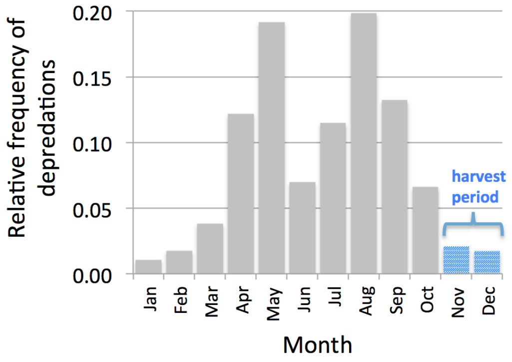

Fig. 7. Seasonal occurrence of depredation events in Michigan, 1996-2012. Only 3.8% of depredations occur during the planned harvest season.

Frequency of estimating wolf abundance

The MI-DNR has stated that the planned harvest "*is extremely unlikely to impact the overall UP wolf population size. We expect the population trajectory to remain unchanged despite the harvest recommended in this memo*." (MI-DNR 2013). The concern with this expectation is that the MI-DNR is planning to estimate wolf abundance no more than once every other year. Significant declines in abundance are difficult to detect in a timely manner when abundance is estimated less than once a year. A scientifically sound harvest plan would include an adequate statistical assessment of the MI-DNR's ability to detect declines in wolf abundance should they occur. No such assessment has been provided.

This concern is well justified because conducting such an assessment is not difficult, and the risk of realizing an unexpected, undesirable decline is not hyperbolized. For example, the state of Minnesota also planned to harvest wolves in a way that would not "have a major influence on overall wolf numbers" (Smith 2013). Despite their expectations, they have been surprised. In 2013, Minnesota suddenly and drastically reduced hunting quotas by 50% upon realizing that wolf abundance had declined by 24% during a five-year period, between 2008-2012. The causes for that decline, and the influence of harvest on that decline, are not adequately understood.

Adaptive management & success criteria

Plans to harvest wolves for the purpose of managing depredations are characterized by considerable scientific uncertainty, to say the least (e.g., Table 1). In such circumstances, the scientific soundness of a plan *requires* the proper application of adaptive management. The MI-DNR has implied that it would adopt such principles, when it wrote, for example, (MI-DNR 2013), "*…we will evaluate and make recommendation to the NRC to adjust the WMUs, bag limits, and harvest targets periodically, if necessary.*"

Adaptive management is not an informal, imprecise sentiment whereby some actions are implemented and then adjusted "if necessary," without specifying in any way what "if necessary" means. For example, would a decline in depredations indicate that the hunt had been effective and no longer necessary? Or would a decline indicate that the hunt has been effective and thereby justify the need for more hunting to further reduce complaints?

The application of adaptive management requires:

- *(i)* *Transparent articulation of measurable goals*. In particular, the goal is to reduce depredations by what amount? Answering this question is critical because it is unreasonable to think that depredations will be reduced to zero, and it is also unreasonable to consider a harvest successful if it reduced depredations by, say, one or two depredation events per year.
- *(ii)* *Transparent use of existing data to evaluate the likelihood that planned management actions would result in achieving management goals*.
- *(iii)* *Transparent specification, in advance, of how one would expect to alter management actions, should the goal not be achieved*. These expectations may change over time, but the development of some kind of *a priori* expectations is vital.

Scientifically-sound management and the principles of adaptive management also require the transparent specification of plans for how future outcomes of the management actions will be analyzed. In particular, suppose that wolves are harvested and depredations decline. How much of a decline would have to be observed to conclude that the decline was not simply due to chance variation? For example, suppose depredations declined from the 41 observed in 2012 to 25. A decline of that magnitude would be consistent with past variation[10] and would not, according to the principles of sound science, be attributed to harvest. The statistical uncertainty associated with the number of depredations indicates the need to think carefully in advance about how harvesting's effect on depredations will be evaluated.

Moreover, wolf abundance is not the only factor affecting depredations. For example, in Minnesota, a significant decline in depredations during the past year is thought to be caused, not by the wolf harvest, but by the previous year's relatively severe winter, which made it easier for wolves to survive on wild prey (Smith 2013). A similar relationship is also well documented in Michigan (Edge et al. 2011; see also Mech 1998). A scientifically sound plan would address the concern that declines in depredation can be caused by factors other than wolf abundance.

This concern is highlighted by observations from western states that experience depredations by wolves. In particular, the frequency of depredations has declined in all three states (Idaho, Montana, and Wyoming). Moreover, the greatest declines were in Wyoming where there has not been any harvesting. That pattern is consistent with two

---

[10] This is because the 80% CI for the number of depredations when there are about 675 wolves is [23.3,50.3]. See also Table 1.

concerns: (i) harvesting is not an important cause of declining depredations and (ii) harvesting may even work against processes that reduce depredations (as suggested by Wyoming experiencing a greater reduction in depredations than Montana and Idaho).

For emphasis, these are not optional elements of management, if management is to be based on sound science. They are required. Plans for harvesting wolves in Michigan do not include any of these elements. While addressing these issues requires considerable care and thought, they are not onerous or expensive. Failure to provide those elements is unequivocal evidence that those plans are not based on sound science, and consequently do not meet the requirements of Michigan state law (i.e., Proposal G, 1996). The transparency afforded by these elements is also something that citizens deserve, both those who appreciate wolves as well as those who do not.

Conclusion

These circumstances would all be very unfortunate if there were no effective means of managing depredations. However, experience suggests that such means exist. For example, Edge et al. (2011), which was authored by two MI-DNR biologists, states:

> "*Proven methods of limiting wolf predation include, management of birthing dates to limit exposure of young, herding vulnerable animals at night, combining herds as to not spread livestock across pastures, and locating birthing of young within barns… Use of an integrated management approach that emphasizes prevention methods and includes prompt responses to predation events and judicious use of compensation, may help decrease predation events, increase tolerance, and alleviate economic losses caused by wolf predations.*"

Edge et al. (2011) makes no suggestion that wolf harvesting would be a sensible means of managing depredations. Rather, the data presented in Edge et al. (2011) and interpretation of that data provided by Edge et al. (2011) are suggestive that wolf harvesting would not be a sensible means of managing depredations. The analysis presented here in this document confirms what is suggested by Edge et al. (2011). The mutually reinforcing nature of this analysis and Edge et al. (2001) is ironic and disturbing insomuch as the MI-DNR asserts (without demonstration) that Edge et al. (2011) is significant scientific support for the idea that a wolf harvest is a sensible means of managing depredations.

The analysis presented here focuses on the assessment of depredations. Only the most modest extrapolation of this analysis is required to be deeply concerned that the MI-DNR plans to harvest wolves for the purpose of managing threats to human safety is also scientifically unsound. If necessary, we can provide such an analysis.

The analysis presented in this document provides clear indication that plans to harvest wolves as a means of managing depredations are not scientifically sound. While this is the case, the state of Michigan should refrain from harvesting wolves.

REFERNCES

Adams, L.G., Stephenson, R.O., Dale, B.W., Ahgook, R.T. & Demma, D.J. (2008) Population dynamics and harvest characteristics of wolves in the central Brooks Range, Alaska. *Wildlife Monographs* 170: 1–25.

Brainerd S. M., Andren H., Bangs E.E., et al. 2008. The effects of breeder loss on wolves. *Journal of Wildlife Management* 72:89-98.

Bangs, E. E., and J. Shivik. 2001. Managing wolf conflict with livestock in the Northwestern United States. *Carnivore Damage Prevention News* 3:2–5.

Beckmann, J. P., and J. Berger. 2003. Rapid ecological and behavioral changes in carnivores: the responses of black bear (Ursus americanus) to altered food. *Journal of Zoology* 261:207-212.

Bunnefeld, N., J. D. C. Linnell, J. Odden, M. A. J. van Duijn, and R. Andersen. 2006. Risk taking by Eurasian lynx (Lynx lynx) in a human-dominated landscape: effects of sex and reproductive status. *Journal of Zoology* 270:31-39.

Chavez, A. S., and E. M. Gese. 2006. Landscape use and movements of wolves in relation to livestock in a wildland–agriculture matrix. *Journal of Wildlife Management* 70:1079-1086.

Daft, R. L. and D. Marcic. 2012. *Understanding Management*. 8th ed. Cengage Learning, 720 pages.

Edge JL, DE Beyer, JL Belant, MJ Jordan, BJ Roell. 2011. Livestock and domestic dog predations by wolves in Michigan. *Human–Wildlife Interactions* 5:66–78.

Gibeau, M. L., A. P. Clevenger, H. S., and J. Wierzchowskie. 2002. Grizzly bear response to human development and activities in the Bow River Watershed, Alberta, Canada. *Biological Conservation* 103:227-236.

Hebblewhite, M. and E. Merrill. 2008. Modelling wildlife-human relationships for social species with mixed-effects resource selection models. *Journal of Applied Ecology* 45: 834-844

Kunkel, K. 2013. *Wolf –livestock conflict assessment and action plan forward for the 21st century*. Abstract submitted to the International Wolf Symposium 2013, Duluth, MN.

Larrucea, E. S., P. F. Brussard, M. M. Jaeger, and R. H. Barrett. 2007. Cameras, Coyotes, and the Assumption of Equal Detectability. *Journal of Wildlife Management* 71:1682–1689.

Mech, L. D., S. H. Fritts, and W. J. Paul. 1988. Relationship Between Winter Severity and Wolf Depredations on Domestic Animals in Minnesota. *Wildlife Society Bulletin* 16: 269–272.

Michigan Department of Natural Resources. 2013. Memorandum to the Natural Resources Commission, Wolf Regulations, Wildlife Conservation Order Amendment No. 6 of 2013, For Information Only. April 2nd, 2013.

Musiani, M. 2013. *The practice of wolf control to protect livestock and halt decline of wild prey in Canada.* Abstract submitted to the International Wolf Symposium 2013, Duluth , MN.

Roell B.J., D.E. Beyer, P.E. Lederle, D.H. Lonsway, and K.L. Sitar. 2010. *Michigan wolf management report 2009*. Wildlife Division Report No. 3511. Michigan Department of Natural Resources.

Rutledge, L.Y., B. R. Patterson, K. J. Mills, K. M. Loveless, D. L. Murray, and B. N. White. 2010. Protection from harvesting restores the natural social structure of eastern wolf packs. *Biological Conservation* 143:332–339.

Sen, A. 2009. *The Idea of Justice*. Belknap/Harvard.

Smith, D. 2013. Minnesota slashes wolf harvest for 2013 nearly in half. *Star Tribune*, 29 July 2013. URL: www.startribune.com/local/217494861.html

Sweanor, L. L., K. A. Logan, J. W. Bauer, B. Millsap, and W. M. Boyce. 2008. Puma and human spatial and temporal use of a popular California state park. *Journal of Wildlife Management* 72:1076-1084.

Treves, A., and L. Naughton-Treves. 2005. Evaluating lethal control in the management of human-wildlife conflict. Pages 86–106 in R. Woodroffe, S. Thirgood, and A. Rabinowitz, editors. *People and wildlife: conflict or coexistence?* Cambridge University Press.

Treves, A. and K. Ullas Karanth. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide." *Conservation Biology* 17: 1491–1499.

Treves, A., K.A. Martin, A.P. Wydeven and J.E. Wiedenhoeft. 2011. Forecasting environmental hazards and the application of risk maps to predator attacks on livestock. *BioScience* 61:451-458.

van Schaik, C. P., and M. Griffiths. 1996. Activity patterns of Indonesian rain forest mammals. *Biotropica* 28:105-112.

Wallach A.D., E.G. Ritchie, J. Read, A.J. O'Neill. 2009. More than mere numbers: The impact of lethal control on the social stability of a top-order predator. *PloS ONE* 4(9): 1-7, e6861.

Williams, B. 2011. Passive and active adaptive management: approaches and an example. *Journal of Environmental Management* 92: 1371–1378.

APPENDIX A – Calculations in Table 1

The expected number of depredations and the 80% confidence intervals that are reported in Table 1 were calculated using standard regression formula and the R statistical software package. The R commands were:

```
> model<-summary(lm(depred~wolves, data=x))
> newdata = data.frame(wolves=c(675,608,540,472,405))
> predict(lm(depred~wolves, data=x), newdata, interval="predict", level=0.80)
```

The probability that depredations would increase between two subsequent years (i.e., the second from last column in Table 1) was obtained by calculating P(X>Y) = P($X - Y > 0$) , where X is the random variable representing the number of depredations in a year with 675 wolves; and Y is the random variable representing the number of depredations in the subsequent year, given the number of wolves specified by each row of Table 1 (e.g., 608 wolves). The probability distribution of $X - Y$ is $N[\mu_X - \mu_Y, sqrt(Var_X + Var_Y)]$. The expected values for that distribution are derived from column two of Table 1. The variance of X and the variance of Y, which is the variance associated with observing a new observation, in the context of simple linear regression, are each equal to:

$$SE^2_{\hat{y}(x^*)} = s^2_{Y|X} + SE^2_{\hat{\mu}_{Y|x^*}} = s^2_{Y|X} + \sqrt{s^2_{Y|X}} \times \sqrt{\frac{1}{n} + \frac{(x^*-\bar{x})^2}{\sum_n (x_i-\bar{x})^2}}$$

where, $s^2_{Y|X}$ is equal to $(1/(n-2)) \times \Sigma(e_i^2)$. The last column of Table 1 was calculated similarly, except those probabilities represent P($X - Y > 30 - 36.7$).

APPENDIX B – Analysis of data in Figure 4

The data in Figure 4 are from Adams et al. (2008). Of the 41 observations used by Adams *et al*. (2008), five were from the wolf population on Isle Royale (1959-2006). In the analysis presented here, we represent the Isle Royale wolf population as a single observation ($m_a = 0$; $r = 0.03$), representing their population dynamics between 1959 and 2010, where m_a is the rate of anthropogenic mortality and r is the annual population growth rate. Adams *et al*. (2008) considered two other observations to be outliers ([$m_a = 0.02$, $r = 0.62$] and [$m_a = 0.23$, $r = -0.50$]; see Fig. 4). The residuals for these observations, in relationship to the best-fitting, non-linear model (see below), are 2.6 and 3.1 times the standard deviation of the residuals for the entire data set. The magnitude of these residuals suggests it may or may not be reasonable to consider these observations as outliers. We conducted a set of analyses omitting these observations, and another including them. Results for both analyses did not differ appreciably. Figure 4 depicts the result for the analysis excluding these observations.

We fit two models to the North American data, a simple linear model and $y=\beta_0+\beta_1 x^{\alpha}$, where the superscript $\langle$ represent a flexible way to allow for the possibility that the influence of m_a on r_t increases with increasing m_a. The non-linear model was unequivocally more parsimonious than the linear model. Specifically, the linear model was characterized by $R^2=0.60$, an Akaike Information Criterion value (corrected for small sample size; AIC_C) of –124.5, and an AIC weight of 0.01; and the nonlinear model was characterized by $R^2=0.71$, an AIC_C value of –133.5, and an AIC weight of 0.99. The AIC weights indicate the non-linear model is 89 (=0.99/0.01) times more likely than the linear model. The results reported on page 7 of this document are the result of calculations associated with this best-fitting non-linear model. Additional details are available upon request.