# Measuring the social carrying capacity for gray wolves in Michigan

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***Abstract:*** We evaluated the efficacy of a conceptual model to assess social carrying capacity (SCC) for the gray wolf (*Canis lupus*) in its current Upper Peninsula (UP) range in Michigan. We measured 3 points to assess citizen ranges of tolerance: the minimum wolf presence they would tolerate (minimum demand for wolves), the level they prefer and the maximum presence they will tolerate (wildlife acceptance capacity). Mail surveys requested respondents to select from 5 presented scenarios of varying wolf abundance and wolf-human interactions to describe those 3 tolerance levels. Cluster analysis classified respondents into 4 tolerance groups ranging from "intolerant" to "most tolerant". Ordinal regression found levels of tolerance toward wolves in the UP were strongly related to basic beliefs about the benefits of wolves and moderately related to concerns for negative impacts of wolves. Region of residence and hunting participation also predicted tolerance. Although considerable support for the presence of UP

wolves existed, SCC analysis revealed insufficient overlap among group tolerances to establish population goals that would not be met with extensive controversy. This assessment demonstrates a means of profiling SCC for wolves and expands the utility of the social carrying capacity concept for agency planning and management.

***Key Words:*** *Canis lupus; cultural carrying capacity; gray wolf; methods; Michigan; social carrying capacity*

The notion that the social environment determines a wildlife carrying capacity (i.e., cultural or social carrying capacity) is not a recent concept (e.g., Edwards and Fowle 1954). Minnis and Peyton (1995) reviewed the history of the concept and proposed several components to advance it beyond a conceptual theory. Carpenter et al. (2000) modified "wildlife acceptance capacity" (the maximum wildlife population tolerated) to incorporate the SCC innovations proposed by Minnis and Peyton (1995) and proposed a concept of "wildlife stakeholder acceptance capacity" (WSAC). Riley and Decker (2000) applied the WSAC model to public attitudes about cougars in Montana and proposed a number of factors that influenced acceptance. A parallel line of research into social norms has evolved in leisure sciences attempting to establish quantifiable ranges for acceptable visual conditions in natural settings based on Jackson's return potential models (Smyth et. al 2007, Budryk and Manning 2003). Regardless of the term and model used, application of the social carrying capacity theory (SCC) to wildlife management has been hindered by lack of an effective means of assessment (Gigliotti et al. 2000). Social carrying capacity analysis was applied to gray wolves (*Canis lupus*) in Michigan to determine whether an assessment of components proposed by Minnis and Peyton (1995) could provide a profile of SCC that would be useful in Michigan's wolf management planning process.

The purpose here is to demonstrate the SCC survey measurement and the use of cluster analysis to profile the SCC for wolves in Michigan. Space does not allow a broad presentation of findings nor comprehensive consideration of the wolf management situation in Michigan. Beyer et al. (2006) provided further review. We selectively report data that enable the reader to evaluate the approach we used to describe and interpret SCC. Finally, we discuss the validity and potential of this approach to SCC and consider implications of its use for management.

## Overview of the applied SCC model

We used the Minnis and Peyton (1995) model as a theoretical basis for the assessment which accounts for 3 hypothetical points to describe the preferences and tolerances of a social group regarding some species: 1) the minimum level they will tolerate ("minimum demand"), 2) the maximum level they will tolerate ("wildlife acceptance capacity"), and 3) their preferred level (Figure 1). The range between the minimum and maximum defines the latitude of acceptance (LOA) for the group. An SCC is a function of the perceived costs and benefits of human-wildlife interactions that in turn are influenced by the frequency of occurrence. Wolf-related issues are created when stakeholders disagree on the types and extent of interactions that are acceptable. The conceptual model poses that individuals become intolerant and may engage in some issue activity when the frequency of important wolf-human interactions falls outside the range of acceptance. For example, some stakeholders may perceive negative interactions such as livestock depredation rates as excessive. Similarly, other stakeholders may perceive positive interactions to be inadequately provided; e.g., wildlife viewing opportunities, ecological benefits or held existence values.

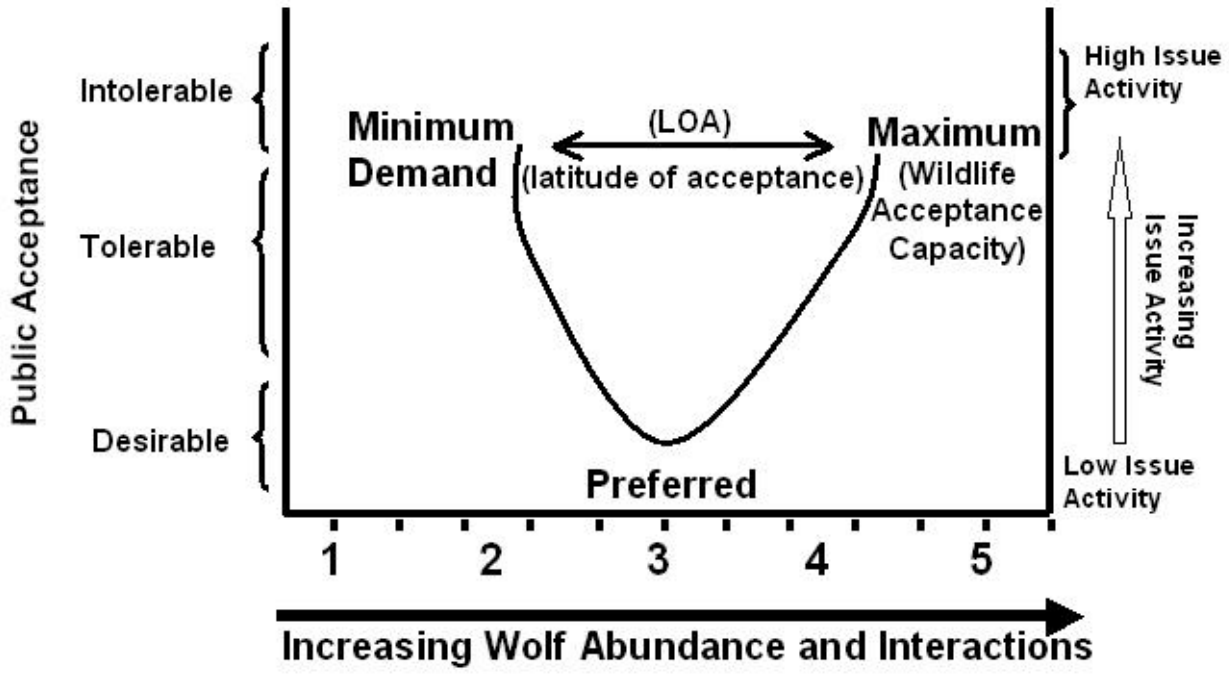


Figure 1. The components of social carrying capacity are illustrated with a single hypothetical stakeholder group's preference and latitude of acceptance between its minimum and maximum tolerances for a species.

Issue management is central to the notion of this SCC model because intense wildlife issues can disrupt management attempts by wildlife agencies. Issues are defined here as wildlife management problems that involve social conflict. Associated issue activity ranges from public demands for agency action to litigation or legislative action by stakeholders seeking resolution. Judicial or legislative intervention removes the management decision from the purview of the state (or federal) resource agencies and they no longer have the opportunity to resolve issues.

Efforts to assess a SCC and incorporate it into management are intended to help avoid these disruptive issues. In application, results of an SCC assessment can suggest the need to address public tolerances (e.g., attitudes) or wolf-human interactions to modify SCC, and/or the assessment may suggest acceptable goals for wolf abundance.

An SCC for wolves is identified for a region when wolf abundance and interactions fall within a range acceptable to most stakeholders and result in a manageable level of wolf-related issues (Minnis and Peyton 1995) (see Figure 2). If management can maintain wolf abundance and interactions within this range of overlapping acceptance, wolf-related issues would be

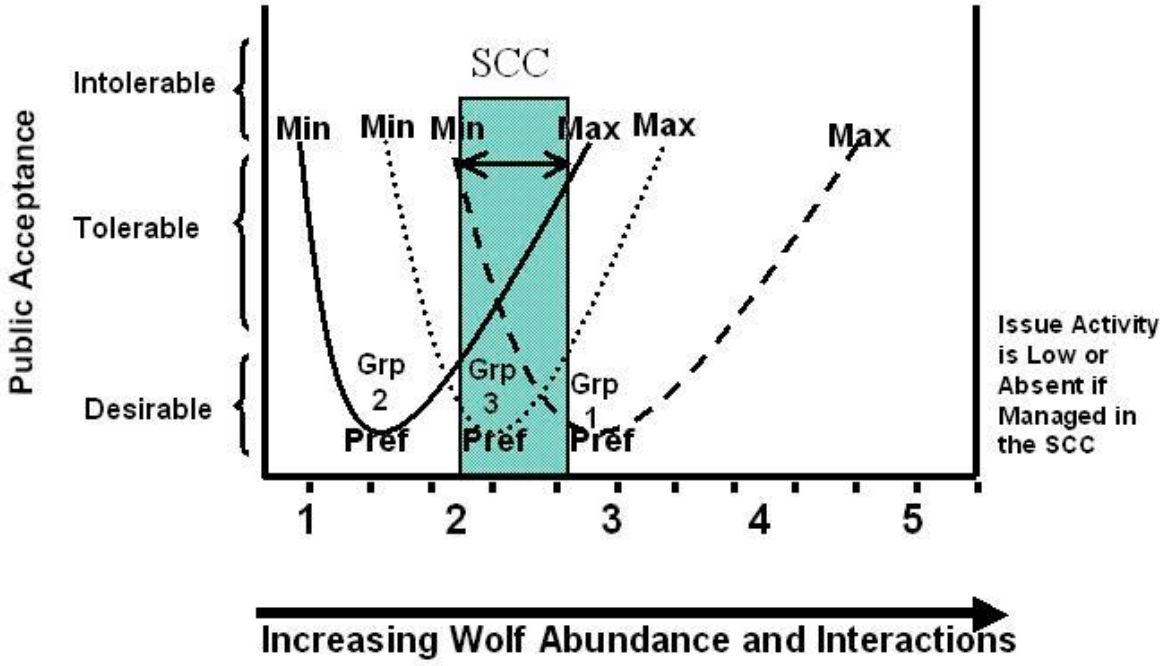


Figure 2. A hypothetical case of 3 stakeholder groups exhibit sufficient overlap among latitude of acceptance ranges to identify a social carrying capacity and suggest an appropriate population goal for a wildlife species.

reduced, even if some or all stakeholder preferences were not optimized. When stakeholders form groups without overlapping ranges of acceptance (i.e., a clear SCC cannot be identified), wolf abundance goals that avoid conflict cannot be easily established.

Discovering that an SCC cannot be identified for a particular wildlife population is still useful for the purposes of guiding wildlife management. If an SCC does not exist – or exists at a level inappropriate for biological (e.g., population viability, biological carrying capacity), legal (e.g., ESA requirements) or other criteria, managing abundance and distribution of wolves may reduce some issues, but create others. In this situation, management may need to address stakeholder attitudes to shift tolerances and create an SCC for wolves. Minnis and Peyton (1995) illustrated a complex cognitive structure (Attitude Response Model; ARM) that would need to be addressed to shift tolerances for white-tailed deer. Riley and Decker (2000) concluded that addressing several public attitudes and beliefs about cougars could productively shift WSAC. Our Michigan SCC survey also explored attitudes regarding specific approaches to the 3 management targets and the results may guide efforts to shift public tolerances (see Beyer et al. 2006). However, those findings are not discussed in this paper. Here, we focus on demonstrating an assessment of SCC that may be useful for other states and/or species.

**Study Region**

By 1960 a viable wolf population no longer existed in Michigan's Upper Peninsula (UP) and in 1964 wolves were given full legal protection in the state. The gray wolf was listed under the Federal Endangered Species Act (ESA) in 1974. The Michigan Department of Natural Resources (MiDNR) gained primary management authority when wolves in the Great Lakes region were removed from the Federal Endangered and Threatened Species List in 2007. The

MiDNR initiated planning in 2004 in anticipation of this reclassification and included a public opinion study to assess socially acceptable goals of wolf abundance and distribution in Michigan.

The statewide survey assessed SCC separately for the presence of wolves in their current range throughout the 15 UP counties, in the NLP (the 26 Lower Peninsula counties north of Isabella County) and in the SLP (the southern 42 Lower Peninsula counties). However, only findings regarding the current wolf range in the UP counties is reported in detail here as a demonstration of the SCC model's application.

Two models have estimated the available wolf habitat in the UP to be between 27,700 $km^2$ (Potvin et al. 2005) and 29,348 $km^2$ (Mladenoff et al. 1999). The wolf population in the UP has steadily increased since the natural recovery began in the early 1990s and increased 12 – 15% each year from 2001 through 2005 (Beyer et al. 2006). The 2004-05 UP winter count indicated at least 434 wolves (Beyer et al. 2006). The biological carrying capacity for UP wolves may be as high as 1300 wolves, about 3 times the 2005 population level (Beyer et al. 2006). About 3% of the state's human population resides in the UP compared to 11% in the NLP and 85% in the SLP. More than 900 livestock farms exist in the UP (USDA 2004), most commonly cattle and calf operations. That represents only about 15% of the number of livestock existing in either Minnesota or Wisconsin wolf range (Beyer et al. 2006).

Wolves have not yet become established in the Lower Peninsula of Michigan (Beyer et al. 2006). However, estimates for NLP wolf habitat have ranged from 8,000 $km^2$ (Potvin 2003) to 4,231 $km^2$ (Gehring and Potter 2005). The NLP counties have an average of 1 farm per 5.1 square miles compared to 1 farm per 18.1 square miles in the UP (Beyer et al. 2006).

## Methods

### Questionnaire design

Potential management issues, research questions, and draft survey items were developed after input from 10 MiDNR public wolf meetings (statewide, May 2005, >500 participants) and from a MiDNR Wolf Working Group. Input from 9 regional stakeholder focus groups (e.g., livestock producers, hunters who used hunting dogs, deer hunters, trappers, and wolf conservationists and protectionists) was used to refine management issues and to develop and revise survey questions. Participants were primarily opinion leaders identified with assistance from MiDNR field supervisors, Michigan State Extension agents and officers of interest groups. Two-thirds of the focus group participants continued to review and comment on evolving versions of the draft survey instrument. We also used select focus group results to help interpret the survey results presented below. A pretest of the survey (N = 400) revealed no undesirable patterns in response rate, missing data or inconsistent responses. The survey was reviewed and approved by the University Committee on Research Involving Human Subjects (IRB#04-524).

Respondents selected their minimum, preferred and maximum levels of UP wolves from 5 situations with different levels of wolf abundance, distribution and wolf–human interactions (Figure 3). Interactions that were described in the situations reflected the key issues identified through the public meetings and focus groups. The 5 situations presented a continuum of abundance/interaction relationships based on experience in the Great Lakes region and a review of scientific literature. Situation 1 described an environment with no wolves and was included to

| | | |
|---|---|---|
| **Increasing wolf numbers** | ***SITUATION 1:*** | ***** No Wolves |
| | ***SITUATION 2:*** | ***** Wolves in a few counties at **very low** numbers<br>***** Rare sightings<br>***** No loss of livestock to wolves in most years<br>***** Rare loss of pets or hunting dogs to wolves<br>***** The Michigan DNR finds no impact on hunter deer harvest due to wolves |
| | ***SITUATION 3:*** | ***** Wolves in many counties but at **low** numbers<br>***** Occasionally seen near rural homes or roads in some areas<br>***** Less than 1% of farms per year lose livestock<br>***** Some loss of pets and hunting dogs likely – less than 10 per year<br>***** The Michigan DNR finds no impact on hunter deer harvest due to wolves |
| | ***SITUATION 4:*** | ***** Wolves exist in **most** counties at **moderate** numbers<br>***** Often seen near rural homes or roads in many areas<br>***** About 1% of farms per year lose livestock (about 7 farms in the UP and 40 in the NLP)<br>***** Pets and/or hunting dogs known to be lost yearly to wolves averages 15 to 20<br>***** The Michigan DNR finds a small decrease in hunter deer harvest is due to wolves |
| | ***SITUATION 5:*** | ***** Wolves exist in **all** counties in the **highest** numbers that can be sustained by the habitat<br>***** Frequent, widespread sightings near rural homes and roads, occasional sightings near towns<br>***** About 2% of farms per year lose livestock (about 14 farms in the UP, 80 in the NLP)<br>***** Pets and/or hunting dogs known to be lost yearly to wolves averages 20 - 25<br>***** The Michigan DNR finds a moderate decrease in hunter deer harvest due to wolves |

Figure 3. The survey presented these 5 situations that were used by respondents to select the preferred level of wolves for a region as well as minimum and maximum levels they would tolerate. Situations were designed based on both known and assumed relationships between wolf abundance and wolf-human interactions in the Great Lakes states.

avoid forcing intolerant respondents into invalid choices or non-response. Situation 5 described a wolf population at biological carrying capacity with high levels of interactions. The levels of depredation in Situations 4 and 5 were conservatively based on Minnesota trends (Harper et al. 2005) and Michigan experiences (Beyer et al. 2006) in view of some uncertainty as whether depredation rates were linearly related to wolf density in areas with low levels of agricultural activity. Situation 3 approximated the combination of wolf abundance and wolf–human interactions existing in the UP in 2005 (respondents were not informed of this). Focus group participants reported they were able to use the described situations successfully in selecting their preferences and tolerances for each of the 3 regions. The survey also assessed concern for specific wolf impacts (interactions) and opinions about associated alternative management options (see Beyer et al. 2006).

**Sampling and mailing procedures**

We surveyed 8,478 Michigan residents (18 years or older) drawn from Michigan driver license records by the Michigan Department of Motor Vehicles (MiDMV). Stratified random samples ensured sufficient regional representation for analysis. The UP (n = 1,491) and NLP (n = 1,991) were sampled separately. The SLP was sub-divided into the SLP rural (27 counties; n = 1,997), SLP metro (12 counties: n = 1,499) and Detroit (3 counties; n = 1,500) areas. Samples were weighted to correct for statewide distribution of respondents when analyses required a statewide interpretation.

We employed a modified Tailored Design Method (Dillman 2000) for mailing. The first questionnaire mailing included an incentive of 3 first class postage stamps ($1.11 value) for the personal use of the respondent. A post card reminder and up to 2 additional surveys were mailed

to non-respondents. The final adjusted response was 60% in the UP and NLP, 56% in SLP rural, 45% in SLP metro and 38% in the Detroit sample.

**Assessment of respondent interest**

The first survey item allowed respondents to identify themselves as "not interested" and fill out only 5 items on the last page before returning the questionnaire. The items addressed age, gender, education and interest in hunting. We excluded disinterested respondents from the SCC analysis and generalized findings to the proportion of citizens interested in wolves. This was consistent with the intended focus on issue activity of the SCC model. Interested respondents were used to calculate weighted statewide distributions of interested citizens, compare regional results and analyze opinions of interest groups (e.g., hunters, livestock producers etc.).

**Data analysis procedures**

Cluster analysis is an exploratory data analysis tool to sort respondents into groups so association among respondents is maximal if they belong to the same group. It can discover structures in data and create taxonomies but does not test hypotheses nor offer explanations. The assumptions of parametric and nonparametric significance tests are violated because clustering methods attempt to maximize the separation between clusters (McClain and Rao 1975, Klastorin 1983, Sarle and Kuo 1993). We used cluster analysis to create tolerance groups based on the preferred, minimum and maximum situations selected by interested respondents for each region. Clusters were created using the SPSS 2-step cluster procedure (SPSS Inc. 2000). Options specified 4 clusters, log-likelihood distance measure and outliers were treated with a noise handling default of 25% (Norusis 1993). Respondents (N = 91) who were uncertain on all 3 SCC questions (i.e. the preferred, highest and lowest wolf situation for the UP) were omitted

from the cluster analysis. This represented 3.5% of interested respondents weighted for statewide distribution. Respondents whose answers did not correspond to any of the patterns used to create the 4 clusters became outliers and were excluded from clusters in order to create the most homogenous groups possible for interpretation. However, data from outliers were used in all non-SCC analyses.

We created variables for beliefs about wolf benefits (BENE) and beliefs about negative wolf impacts (IMPACT) by summing respondent answers to a series of Likert scale questions. When added from responses (ranging from 1 = "not a consideration" to 4 = "very important"; "undecided" was coded missing), the 5 impact items produced a single factor (impact concern score) with a Cronbach's alpha of 0.80 suggesting sufficient internal consistency to collapse individual questions into a summed scale (Nunnally 1978). One-way analysis of variance was performed to assess mean differences among cluster groups on the BENE and IMPACT scale scores.

Prior research has found that attitudes toward wolves are correlated with gender, age, type of residence (i.e. urban versus rural), education and participating in hunting (Naughton-Treves, Grossberg and Treves 2003; Williams, Ericsson and Heberlein 2002; Lohr, Ballard, and Bath, 1996; Pate, Manfredo, Bright, and Tischbein, 1996). Therefore, we used cross tabulations among zone of residence, participation in hunting, age, sex, and level of education to identify variables associated with cluster membership. We determined significance for the Pearson's Chi-square statistic at .05. Demographic variables that demonstrated significant associations with cluster membership were retained for multivariate analysis.

Finally, we utilized polytomous logit universal models (PLUM) for ordinal regression on SPSS 14.0 to test factors that determined respondents' SCC cluster membership. Outliers were removed leaving us with a 4-category, dependent variable ranging from intolerant to most tolerant. We tested four alternative models using combinations of demographic variables and the BENE and IMPACT indices of basic beliefs For model testing, we utilized only those cases (n = 1,654) with complete data for all variables under investigation. An information-theoretic approach was used to determine the best model among several candidate subsets (Burnham and Anderson 2002). The log of the maximum likelihood estimate for each model was obtained from the SPSS print out and used to calculate Akaike Information Criteria (AIC) scores. These scores were corrected to overcome small sample bias ($AIC_C$ scores). In addition, Akaike weights (W) were calculated for each model. Candidate models were judged based on AIC scores, Nagelkerke pseudo$R^2$ values, and percentage of correctly classified cases.

Given the previously cited literature and our significant results of cross tabulations, the first model we tested (model 1) included five demographic variables to predict tolerance level for UP wolves. Four categorical variables and 1 continuous independent demographic variable were advanced: zone of residence (UP, NLP, SLP), hunting orientation (hunter, non-hunter), education, sex and age. Seven education categories were collapsed into 3 for analysis: high school or less, more than high school but less than a 4 year degree, and 4 year degree or more (coded as the indicator variable). Age was a continuous variable. We hypothesized that intolerant group members were more likely to be male, participants in hunting, older, residents of the U.P. and less educated than members in the most tolerant cluster.

The second model included the previous 5 demographic variables with the addition of the respondents' IMPACT and BENE index scores. Model 3 removed the demographic variables and tested the effects of the two belief indices alone. Finally, the fourth model we tested utilized the BENE index as a single independent. Models 2 through 4 enabled us to determine the extent to which measures of basic beliefs improved the predictive capacity over using demographics alone (Vaske, Donnelly, Williams, and Jonker, 2001). We hypothesized that a valid categorization of SCC profiles would be strongly influenced by respondents' basic beliefs regarding wolf interactions. Cognitive hierarchy theory suggests that basic beliefs precede and shape our positive or negative evaluations of attitude objects (in this case, wolf populations) (Whittaker, Vaske, and Manfredo, 2001; Fulton, Manfredo, and Lipscomb 1996).

## Results

### Citizen interest in wolf issues and response patterns

Evaluation of our SCC measurement approach should consider potential biases resulting from non-response. Data provided by the MiDMV enabled a comparison of non-respondents to interested and disinterested respondents. Non-respondents were youngest (44.4 years) followed by interested (50.0 years) and disinterested respondents (57.4 years) ($F$= 247.4, $P < 0.001$). Half (50%) of the interested respondents and non-respondents were male compared to 42% of the disinterested respondents ($\chi^2 = 22.4$, df = 2, $P < 0.001$). About 42% of UP and NLP residents were non-respondents, 44% were interested and 14% disinterested respondents, but the majority of SLP residents were non-respondents (57%) and only 29% were interested respondents ($\chi^2 = 138.9$, df = 4, $P < 0.001$). Statewide, more interested than disinterested respondents were hunters (33% versus 11%; $\chi^2 = 169.2$, df = 6, $P < 0.001$). Interested respondents reported more education

than disinterested respondents; 74% versus 64% had education beyond high school ($\chi^2$= 35.3, df = 4, $P < 0.001$).

Non-response was related to lack of interest in the wolf issues. Residents in the UP wolf range were most likely to respond to the survey and only 21% of those respondents were disinterested. The SLP metro and Detroit samples were least likely to respond and had a substantial portion of disinterested respondents (33% and 39% respectively). The portion of disinterested respondents increased from 19% of first mailing respondents to 66% for the third mailing, suggesting most non-respondents would have indicated "no interest" had they been eventually persuaded to respond.

**Status of SCC for wolves in the UP**

Responses to the SCC questions regarding UP wolf presence (Table 1) were sufficiently homogenous that plotted means for the preferred, minimum and maximum situations present meaningful profiles for comparing the 4 tolerance clusters. The 4 clusters differed in their tolerances towards wolves and were labeled "intolerant", "least tolerant", "mid-tolerant" and "most tolerant". About 13% of respondents were outliers (Table 2). Only 7% of interested respondents failed to choose a preferred, minimum or maximum situation for the UP.

When interested respondents were weighted for statewide distribution, membership in tolerance groups ranged from 7% in the intolerant group to 32% in the most tolerant group (Figure 4). There is little overlap in LOA among the 4 groups to identify an SCC for UP wolf abundance and interactions. The 2005 level of UP wolf abundance and interactions (Situation 3) exceeded maximum acceptance of 27% of the interested citizens but barely satisfied the minimum demand for wolf abundance and interactions of the most tolerant group.

Table 1. UP wolf abundance situations selected as minimum tolerated, preferred and maximum tolerated by tolerance clusters of the general public.

| | Situation Choices of the 4 Tolerance Clusters | | | |
|---|---|---|---|---|
| | Intolerant (N = 263) | Least Tolerant (N = 510) | Mid-Tolerant (N = 615) | Most Tolerant (N = 219) |
| Minimum Tolerated | Situation 1* (100%) | Situation 2 (100%) | Situation 2 (36%)<br>Situation 3 (64%) | Situation 2 (14%)<br>Situation 3 (55%)<br>Situation 4 (30%) |
| Preferred | Situation 1 (100%) | Situation 2 (71%)<br>Situation 3 (29%) | Situation 3 (100%) | Situation 4 (81%)<br>Situation 5 (19%) |
| Maximum Tolerated | Situation 1 (73%)<br>Situation 2 (27%) | Situation 2 (40%)<br>Situation 3 (60%) | Situation 3 (36%)<br>Situation 4 (64%) | Situation 4 (53%)<br>Situation 5 (47%) |

*Situations describe increasingly higher levels of interactions and wolf abundance: Situation 1 had "no wolves", Situation 2 described a viable but low population, Situation 3 described 2005 conditions, Situation 4 described higher levels of interactions and abundance than existed in 2005, Situation 5 described a very high level of interactions and wolf abundance at BCC.

Table 2. UP Wolf abundance situations selected as minimum demand, preferred and maximum tolerated by outliers (N = 347) in cluster analysis.

| | Situation 1* | Situation 2 | Situation 3 | Situation 4 | Situation 5 | Undecided |
|---|---|---|---|---|---|---|
| Minimum Demand | 46% | 14% | 8% | 4% | 16% | 12% |
| Preferred | 11% | 33% | 23% | 9% | 20% | 5% |
| Maximum Tolerated | 2% | 13% | 27% | 19% | 26% | 13% |

*Situations describe increasingly higher levels of interactions and wolf abundance: Situation 1 had "no wolves", Situation 2 described a viable but low population, Situation 3 described 2005 conditions, Situation 4 described higher levels of interactions and abundance than existed in 2005, Situation 5 described a very high level of interactions and wolf abundance at BCC.

**Membership in tolerance clusters**

Four of the five demographic variables showed significant association with cluster membership (Table 3). Overall, a higher percentage of those in the intolerant cluster were UP residents, hunters, less educated, and above the age 60 than were other respondents (Table 3). There were no significant differences between male and female residents. Substantially more interested UP respondents were intolerant of UP wolves than were citizens residing elsewhere in Michigan (Table 3). Statewide, about half of interested hunters were mid-tolerant and most tolerant of UP wolves and less than 10% were intolerant. However, hunters residing in the UP were twice as likely (35%) as NLP hunters (15%) and nearly 4 times more likely than SLP

Table 3. Distribution of residence and hunting interests among tolerance clusters for UP wolves.

| Weighted Stakeholder Segment | UP Wolf Tolerance Clusters | | | | | |
|---|---|---|---|---|---|---|
| | % Intolerant | % Least Tolerant | % Mid Tolerant | % Most Tolerant | % Outliers | % Total |
| Interested Public (N = 2,410)[a] | 7 | 20 | 28 | 32 | 13 | 100 |
| UP Residents (5%) | 24 | 21 | 20 | 17 | 17 | 100 |
| NLP Residents (16%) | 10 | 20 | 27 | 28 | 15 | 100 |
| SLP Residents (79%) | 5 | 20 | 29 | 33 | 12 | 100 |
| Education level [b] | | | | | | |
| High school or less (24%) | 10 | 23 | 26 | 27 | 14 | 100 |
| >high school and <college degree (42%) | 9 | 22 | 28 | 30 | 12 | 100 |
| 4 yr degree or more (34%) | 3 | 17 | 30 | 38 | 12 | 100 |
| Gender [c] | | | | | | |
| Male (49%) | 8 | 20 | 27 | 32 | 14 | 100 |
| Females (51%) | 7 | 21 | 29 | 31 | 12 | 100 |
| Age [d] | | | | | | |
| 18-30 years old | 6 | 17 | 25 | 30 | 12 | 100 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 31-59 years old | 8 | 19 | 22 | 28 | 13 | 100 |
| 60 and over | 14 | 23 | 23 | 17 | 13 | 100 |
| Hunters (N = 793)[e] | 12 | 21 | 26 | 28 | 13 | 100 |
| UP Residents (8%) | 35 | 19 | 16 | 11 | 19 | 100 |
| NLP Residents (24%) | 15 | 21 | 24 | 23 | 16 | 100 |
| SLP Residents (68%) | 9 | 21 | 28 | 32 | 11 | 100 |
| Non-hunters (N = 1,591)[f] | 5 | 20 | 28 | 34 | 13 | 100 |
| UP Residents (3%) | 12 | 22 | 27 | 25 | 14 | 100 |
| NLP Residents (12%) | 5 | 20 | 29 | 32 | 13 | 100 |
| SLP Residents (85%) | 4 | 20 | 28 | 35 | 12 | 100 |

a. Goodness of fit for all interested public by region of residence: $\chi^2 = 78.9$, df = 8, $P < 0.001$
b. Goodness of fit for all interested public by education level: $\chi^2 = 59.1$, df = 8, $P < 0.001$
c. Goodness of fit for all interested public by gender: $\chi^2 = 3.64$, df = 4, $P < 0.455$
d. Goodness of fit for all interested public by age: $\chi^2 = 19.7$, df = 8, $P < 0.003$
e. Goodness of fit for hunters by region of residence: $\chi^2 = 52.4$, df = 8, $P < 0.001$
f. Goodness of fit for non-hunters by region of residence: $\chi^2 = 8.7$, df = 8, $P = 0.368$

hunters (9%) to be intolerant of UP wolves. They were also less likely to be most tolerant. Two-thirds of interested citizens statewide were non-hunters with slightly higher tolerances than hunters for UP wolf abundance. However, even among non-hunters, UP respondents were more than twice as likely to be intolerant as NLP and SLP non-hunters and fewer UP non-hunters were most tolerant.

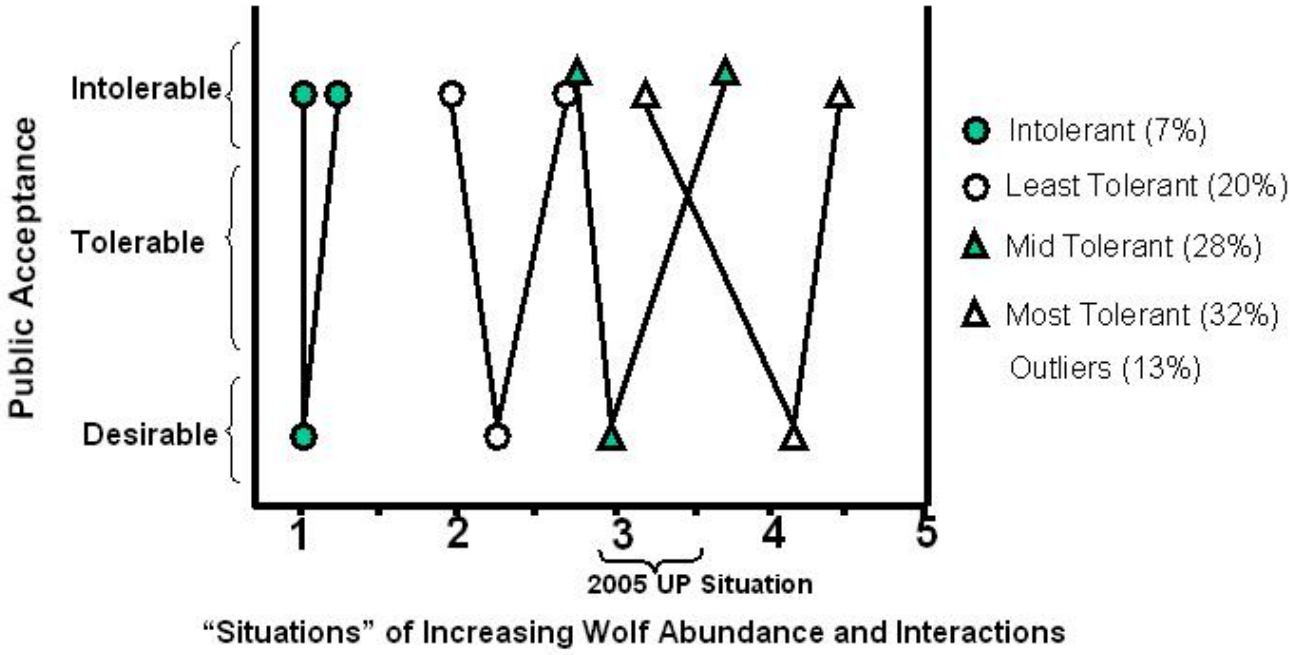


Figure 4. The 4 statewide tolerance groups created by cluster analysis from responses to the 3 UP wolf questions. Each cluster is plotted with 3 points: the minimum abundance/interactions they will tolerate (minimum demand), the maximum they will accept (wildlife acceptance) and the level preferred by the group. Outliers had responses that could not be fitted into any of the 4 clusters.

**Selected attitudes of the SCC tolerance groups**

We asked respondents the importance of 8 benefits as reasons for having wolves in Michigan (Table 4). Responses ranged from "not a reason" to "very important reason" (coded 1 through 4, respectively; "undecided" was coded as missing). Intolerant respondents did not rate any of the proposed benefits as an important reason to have wolves in Michigan. The more

tolerant groups tended to rate all benefits except the eventual game species status of wolves as important reasons to have wolves in Michigan. While all 4 clusters rated game species status very low, 80% of the intolerant and half of the most tolerant respondents agreed the wolf should be a game species with a controlled legal hunting season.

We also assessed respondents' evaluation of negative wolf impacts. Respondents were asked how much importance they would assign to each of 5 impacts when considering whether to reduce wolf numbers in some area. There was a tendency for assigned importance of impacts to be lower among more tolerant groups, but the mean importance scores of each remained relatively high (Table 5). This is counter to positions of very strong wolf advocates among our focus group participants. For example, they dismissed domestic animal depredation as an unimportant cost to livestock producers and considered public safety concerns to be unwarranted.

**Predicting membership in SCC clusters**

Comparing the PLUM results showed respondents' basic belief scores regarding wolf benefits and impacts were stronger influences on their SCC cluster membership than were demographic measures (Table 6). Model 4 containing the benefit index as the sole independent variable achieved the lowest $AIC_c$ score (505.7) and an Akaike weight of 1 suggesting the best and most parsimonious fit for the data set. However, it also produced a lower pseudo $R^2$ and a lower classification accuracy than did models that included IMPACT scores (model 3) and both IMPACT and demographic variables (model 2) suggesting some degree of acceptability for these models as well (Table 6).

Table 4. Mean ratings of benefits as reasons to have wolves in Michigan by the 4 UP wolf tolerance clusters (1 = not a reason, 2 = slightly important reason, 3 = somewhat important reason, 4 = very important reason).

| Benefit statement | UP tolerance level | | | | F (df) | p |
|---|---|---|---|---|---|---|
| | In | LT | Mid | MT | | |
| As predators, wolves could benefit Michigan's ecosystem by helping to control some other wildlife | 1.2 | 2.5 | 3.2 | 3.5 | 557.0 (3,2007) | .001 |
| There are people who appreciate wolves and want to know that wolves exist in Michigan. | 1.2 | 2.1 | 2.7 | 3.0 | 256.7 (3,2012) | .001 |
| Future generations of citizens could benefit if we maintain wolves in Michigan. | 1.2 | 2.3 | 3.0 | 3.4 | 473.7 (3,1961) | .001 |
| Wolves had a historic presence in Michigan and should be here now | 1.1 | 2.4 | 3.1 | 3.4 | 482.9 (3,2013) | .001 |
| People want to view, hear, photograph or study wild wolves in Michigan. | 1.2 | 2.3 | 2.9 | 3.1 | 334.3 (3,2009) | .001 |
| Regardless of our laws, wolves have a right to exist in Michigan. | 1.7 | 2.4 | 3.2 | 3.5 | 414.3 (3,1998) | .001 |
| Wolves could increase tourism in Michigan and provide economic benefits. | 1.1 | 1.9 | 2.4 | 2.6 | 173.6 (3,1985) | 0.001 |
| Wolves could eventually become another game species for Michigan hunters. | 1.3 | 1.7 | 1.9 | 1.9 | 26.3 (3,1998) | 0.001 |

Table 5. UP Tolerance group responses to "If...asked...whether wolf numbers should be reduced...how important would each of these be to you in considering your position?" (1 = not a consideration, 2 = slightly important, 3 = somewhat important, 4 = very important)

| "...how important would each of these be to you...?" | UP tolerance level | | | | *F* (df) | *P* |
|---|---|---|---|---|---|---|
| | In | LT | Mid | MT | | |
| the number of farm animals actually lost to wolves. | 3.7 | 3.7 | 3.4 | 3.1 | 82.7 (3,2028) | .001 |
| a lower percent of deer hunters who harvest deer if it is actually caused by wolves preying on deer. | 3.4 | 3.0 | 2.6 | 2.2 | 113.5 (3,2004) | .001 |
| the number of hunting dogs actually lost in the field to wolves | 3.5 | 3.2 | 2.8 | 2.3 | 133.8 (3,2015) | .001 |
| a concern among area residents for human safety caused by a high number of confirmed wolf sightings near homes | 3.8 | 3.8 | 3.6 | 3.2 | 56.4 (3,2031) | .001 |
| the number of pets actually attacked by wolves near the pet's home. | 3.7 | 3.8 | 3.5 | 3.1 | 86.5 (3,2031) | .001 |

Using both BENE and IMPACT improved the overall classification accuracy by 9% compared with using BENE alone. Parameter estimates for model 3 indicate that as BENE scores increase so does the tolerance for wolves, whereas there was a negative relationship between IMPACT scores and tolerance (Table 7).

Table 6. Evaluation information comparing four polytonous logit universal models (PLUM) for determining influences on SCC group cluster membership.

| Model | Nagelkerke $R^2$ | % correct | £ | *K* | $AIC_c$ | $\Delta_i$ | Akaike weights[1] |
|---|---|---|---|---|---|---|---|
| 1 (demographics) | .15 | 40 | -1718.9 | 6 | 3443.0 | 2937.3 | 0 |
| 2 (demographics plus IMPACT and BENE indices) | .58 | 57 | -1566.2 | 8 | 3139.5 | 2633.8 | 0 |
| 3 (IMPACT and BENE indices) | .56 | 56 | -.781.2 | 3 | 1558.5 | 1052.8 | 0 |
| 4 (BENE only) | .49 | 47 | -252.3 | 2 | 505.7 | 0 | 1 |

[1] For ease of reporting, Akaike weights for models 1, 2, and 3 are listed as zero, though technically they each produce infinitesimally scale decimal values.

Table 7. Polygonous logit universal model parameter estimates for the influence of basic belief indices about wolves on SCC cluster membership.

| | | Estimate | Std. error | Wald | Sig. |
|---|---|---|---|---|---|
| Model 3 | | | | | |
| Threshold | Cluster 1 | -2.07 | .337 | 37.7 | .000 |
| | Cluster 2 | .315 | .336 | .881 | .348 |
| | Cluster 3 | 2.31 | .341 | 45.9 | .000 |
| Location | INDEX | -.230 | .016 | 195.6 | .000 |
| | BENE | .235 | .009 | 620.548 | .000 |
| Model 4 | | | | | |
| Threshold | Cluster 1 | .236 | .156 | 223.0 | .000 |
| | Cluster 2 | 4.56 | .190 | 574.7 | .000 |
| | Cluster 3 | 6.36 | .220 | 834.6 | .000 |
| Location | BENE | .259 | .009 | 765.0 | .000 |

The worst performing model was the one featuring the 5 demographic variables (zone of residence, hunting participation, age, gender, and education). Demographics alone explained only 15% of the variance in cluster membership and correctly classified only 40% of the cases (Table 8). All four models more successfully predicted membership in the intolerant cluster compared to other tolerance clusters (Table 8). The BENE-only model correctly classified 81% of the intolerant SCC members and 56% of the most tolerant group.

Table 8. Percentage of correct classification for predicting cluster segment membership resulting from regression models.

| Model | % of correctly classified cells within 4 cluster groups | | | | Overall % correct |
|---|---|---|---|---|---|
| | Intolerant | Least tolerant | Mid-tolerant | Most tolerant | |
| 1 | 57 | 28 | 33 | 44 | 40 |
| 2 | 74 | 54 | 44 | 61 | 57 |
| 3 | 73 | 52 | 44 | 62 | 56 |
| 4 | 81 | 48 | 41 | 56 | 47 |

**Respondents' ability to discriminate among regions in choosing situations**

We examined responses to the SCC questions for the UP and NLP regions to determine whether they reflected the substantial social and ecological differences that exist. A positive finding would provide support for a valid measure of tolerances and demands. It is reasonable to expect that many respondents would have less tolerance and demand for wolves to inhabit the more heavily populated and developed southern regions of the state. We compared respondents'

choices of preferred, minimum, and maximum situations for the UP and NLP with the SPSS paired sample t-test. Mean difference scores were significantly different; i.e., individuals tended to answer differently for the zones (minimum- $t = 11.0$, $P < 0.001$; preferred- $t = 15.1$, $P < 0.001$; maximum - $t = 18.7$, $P < 0.001$). Half of the respondents who preferred the highest level of wolves for the UP preferred a lower level for the NLP. Members of the 2 moderate clusters tended to prefer lower wolf situations for the NLP than for the UP.

## Discussion

The SCC concept has had limited use in wildlife management due to difficulty in measuring and describing this capacity. We demonstrated success in measuring the SCC for wolves in Michigan by designing a range of situations that described wolf abundance and related interactions. Most respondents were able to select situations to define 3 points in the SCC model: the minimum situation they could accept (reflecting a minimum demand), the situation they preferred and the maximum situation they would tolerate (wildlife acceptance capacity). Use of cluster analysis was effective to identify and describe the profiles of Michigan tolerances that indicated the status of SCC. The identified clusters complemented the traditional use of interest group segments to analyze public attitudes for the purpose of developing management strategies.

This SCC assessment required available data on the distribution and frequency of important negative interactions (e.g., depredation on domestic animals) and a reliable estimate of (minimum) wolf abundance created by MiDNR annual winter track counts. The inferred abundance/interaction relationships enabled the design of a plausible 5-level continuum to measure stakeholder preferences and tolerances.

**Evaluation of the SCC measurement items**

Further experience and research will be required to refine the SCC measures; however, some evidence suggests the approach is an effective tool for respondents. The low frequency of missing and "undecided" answers among survey respondents suggests they were able to use the items. A low portion (5%) of respondents gave blank or "undecided" responses to all UP, NLP and SLP SCC questions. Further support was indicated by feedback from 9 focus groups and a follow up review panel of 52 participants that suggested they understood and appropriately interpreted the 5 scenarios and could easily select preferred and unacceptable situations for the UP.

Survey respondents apparently could apply the situations differently to the 3 regions of Michigan where social and ecological conditions differed. This suggests respondents considered regional consequences of wolf abundance as intended by the instrument rather than responding to an over-riding positive or negative attitude towards the wolf species. A possible "protest response" by UP residents who selected the maximum number of wolves as their preferences for the SLP did not materialize. Only 12 respondents preferred no wolves for the UP but preferred the maximum level for the SLP.

Relationships found between the membership in tolerance clusters and both benefit scores and impact concerns support the validity of the cluster analysis. As expected, the more tolerant clusters scored benefits higher than less tolerant groups. However, cluster membership was less strongly related to concerns for impacts suggesting that although the highly tolerant clusters are more accepting of impacts, they would accept management to control the impacts.

**Validity threats and assumptions of the measurement approach**

The SCC assessment is limited to an assumption that a lack of overlapping tolerances among clusters would predict more stakeholder issue activity. Our survey addressed neither the factors impinging on an individual's actual behavior, nor respondent intentions to take action regarding Michigan wolf management. Further research is required to test the relationship between non-overlapping tolerances and issue activity predicted by the SCC concept used.

Our focus on citizens who were interested in wolf issues was consistent with the goal of the Minnis and Peyton model to describe social tolerances and predict issue activity. However, the omission of uninterested recipients from the SCC profile assumed that if these citizens became interested at a later time, their attitudes and intentions would reveal patterns similar to those described. Although we saw no evidence to suggest it, we acknowledge the potential for the public with latent interests to have patterns of concern different than those described.

Another limitation lies in the development of the situations used to measure respondent demand, preference and tolerance for wolf presence. A basis existed to infer relationships between abundance and interactions; however, those relationships could not be precisely described. This limited our ability to interpret tolerances as specific quantitative levels of wolf abundance and interactions. Further, the combinations we selected for situations would influence responses. For example, we conservatively truncated the depredation rates in situations 4 and 5 to present what the MiDNR Wolf Working Group judged to be a most likely "worst case scenario" appropriate for management decisions in the UP. A more extreme "worst case scenario" would likely have shifted cluster membership.

## Theoretical considerations

The literature has advocated assessing SCC by segmenting on traditional interest groups (e.g., Carpenter et al. 2000); however, our survey showed that SCC for wolves was associated with substantial variability in tolerances within traditional interest groups. Tolerances among both hunters and non-hunters varied with region of Michigan and within a region, hunters were found in all 4 tolerance clusters. Cluster analysis of respondents based on their preferred and unacceptable levels of wolf abundance was shown to add utility as a segmentation tool for describing the SCC in Michigan.

Given these results, we propose retaining the terminology "social carrying capacity" for this concept. First, "social carrying capacity" encourages application to a society of interested citizens (who are stakeholders) and broadens the approach beyond traditionally defined interest groups. Second, it avoids the term "wildlife acceptance" that implies a maximum acceptable level of abundance (Decker and Purdy 1988) and embraces a holistic consideration of minimum demand and preferred level as well as maximum acceptance.

## Management implications

The SCC profile lacks sufficient overlap among tolerance and demand to identify a UP wolf abundance goal for the region that would not have strong potential for public conflict. The evidence suggests that the 2005 level of abundance of wolves and their associated interactions with humans (described in situation 3) was approaching an intolerant level for a majority of Michigan citizens, most especially those who lived within wolf range. The overlap of the mid-tolerant group with the least and most tolerant groups is encouraging but the wide range between "intolerant" and "most tolerant" respondents poses potential conflict. In actual use, the agency

must interpret the consequences of setting wolf policy on the basis of an SCC profile and determine the strategies to be used. A reasonable interpretation would be that interactions in 2005 are reaching a critical level and some management response will be needed to address tolerances, interactions and/or wolf abundance. Statewide, a very small minority (7%) of interested citizens can be expected to be intolerant of wolves. However, that includes 25% of UP interested citizens with a large portion of organized livestock producers and hunters. This presents a large potential for conflict.

A major task for Michigan wolf management will be to shift the range of tolerances to create some acceptable level of wolf abundance and wolf/human interactions. Findings reported here illustrate opportunities to approach this need. For example, all groups share some value for benefits of wolves that could be used to advantage in developing information messages to shift tolerances. Also, because the most tolerant respondents tended to place importance on impacts of wolves, they may be receptive to proposed control of regional wolf abundance if that became necessary. Management efforts to increase public awareness of both the impacts of these interactions and the efficacy of control could shift tolerances to accept lower wolf abundance. Other results of the survey reported in Beyer et al. (2006) described details of public opinion on wolf management options and suggested means to gain more public agreement on population goals and management strategies. Riley and Decker (2000) made similar recommendations regarding the utility of the Stakeholder Wildlife Acceptance Capacity model they applied to Montana cougar management.

The 2005 level of UP wolf abundance (Situation 3) barely satisfied the minimum demand for wolf abundance and interactions of the most tolerant third of interested respondents

statewide. Yet, wolves were already present at or beyond the maximum level tolerated by a substantial portion of interested citizens, especially UP residents. Given the estimated biological carrying capacity for wolves in the UP and the rate of population growth, the potential exists for UP wolf abundance and interactions to quickly surpass the maximum acceptance of 2/3 of Michigan's interested citizens.

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