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Toward an understanding of beaver management as human and beaver densities increase

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Abstract: Estimates of beaver (*Castor canadensis*) density play an important role in wildlife managers' decisions about beaver population management, because managers anticipate higher incidence of problem complaints when a beaver population increases. To manage the impacts of beavers in an urbanizing landscape, managers need better information on changes in stakeholder beliefs and attitudes as beaver and human densities reach high levels. We conducted additional analysis of data collected in 2002 through mail surveys of residents in New York and Massachusetts to test hypothesized relationships between beaver density and damage experience, attitudes toward beavers, and norms about beaver management actions. Consistent with previous research, we found a correlation between personal experience with beaver-related problems, lower acceptance capacity for beavers, and higher acceptability of lethal beaver management actions. In comparison to residents living in areas with low beaver density, residents of areas with high beaver density were more likely to: experience beaver-related problems; believe that beaver-related damage had greatly increased in their area; express a preference for beaver population reduction; express less tolerant attitudes toward beaver presence; and accept lethal control of beavers as a response to beaver-related problems. These findings add to understanding of wildlife acceptance capacity, generally, and tolerance of beavers specifically. Based on our findings, we propose a conceptual model representing key dynamic interrelationships between stakeholder attitudes, norms, and common beaver management practices. We discuss a causal loop diagram representing the model to illuminate the challenges wildlife managers are likely to face as the context for beaver management changes. The model articulates the dynamic complexity of urban beaver management and fills a gap in the literature by conceptualizing beaver management as a coupled human–natural system. Such models may aid communication in locales where high densities of beaver and people set the stage for human–wildlife conflict and emergence of disruptive wildlife management issues.

Key words: attitudes, beaver, damage tolerance, density, human–wildlife conflict, management, model, wildlife acceptance capacity

Estimates of beaver (*Castor canadensis*) density play an important role in wildlife managers' decisions about beaver population management. Some states (e.g., New York) establish beaver density goals and base decisions about trapping season length on beaver density estimates (i.e., season length is increased if estimated beaver density exceeds an established beaver density goal; Runge 1999). Managers attend to beaver density estimates because they expect a higher incidence of beaver-related problems when a beaver population increases (Bhat et al. 1993, Deblinger et al. 1999; Figure 1). Through careful record keeping and beaver population assessment, wildlife agencies can clarify the relationship between beaver density, human land uses, and stakeholder complaints about beaver-related problems. An unpublished analysis of agency records in New York State, for example, showed a strong correlation between beaver density and number of complaints about beaver-related problems (P. Jensen, New York State Department of Environmental Conservation, personal communication).

Documenting the relationship between beaver densities and stakeholder attitudes and beliefs also can be valuable as input to beaver management decisions, but multiple investigations on different facets of wildlife-problem tolerance are needed to gain such insights. In the late 1980s, the New York State Department of Environmental Conservation (NYSDEC) began sponsoring periodic research to measure and understand tolerance to beaver

Figure 1. Increasing beaver (*Castor canadensis*) density in areas with high human populations set the stage for human–wildlife conflict and emergence of disruptive wildlife management issues. (*Photo: ©Matthieu Nicou, <Fotolia.com>. Reprinted with permission.*)

damage (Purdy and Decker 1985; Enck et al. 1988, 1992, 1996). Findings from those studies contributed to a body of literature on the general relationship between wildlife population size and tolerance for species.

More recent research filled some important gaps in understanding of stakeholder belief and attitude change as people experience beaver-related problems. In 2002, NYSDEC and the Massachusetts Division of Fisheries and Wildlife (MassWildlife) supported collaborative research focused on the relationship between beaver-related problem experience and (a) attitudes toward beavers, (b) wildlife acceptance capacity, and (c) attitudes toward beaver management actions. Findings from complementary studies in Massachusetts and New York were reported separately (Jonker et al. 2006, 2009; Siemer et al. 2004*a*). In this paper, we report results of additional analysis that combines data collected in 2002 to replicate tests of hypothesized relationships between beaver density and damage experience, attitudes toward beaver, and norms about beaver management actions.

Based on our findings, we propose a conceptual model representing key dynamic interrelationships between stakeholder attitudes, norms, and common beaver management practices. We discuss a causal loop diagram (Sterman 2000) representing the model to illuminate the challenges wildlife managers are likely to face as the context for beaver management changes in coming years. The model articulates the dynamic complexity of urban beaver management and fills a gap in the literature by conceptualizing beaver management as a coupled human-natural system.

Hypotheses

Knowledge about the factors that drive wildlife acceptance capacity (WAC) is growing (Decker and Purdy 1988). Studies reveal that WAC (i.e., the wildlife population level in an area that is acceptable to people) varies by stakeholder group, species of wildlife, and geographic locale. Other factors associated with WAC include: the type, amount, and severity of damage; stakeholders' ability to withstand the economic consequences of damage; personal attitudes toward wildlife; perceptions of wildlife population trends; and attitudes toward hunting (Siemer and Decker 1991, Conover 2002).

Several studies, most of which focused on interactions between humans and white-tailed deer (*Odocoileus viginianus*), suggest that personal experience with wildlife damage can affect WAC and acceptability of lethal wildlife management actions. These studies indicate that acceptance of lethal management tends to be higher among people who have personally experienced problems with wildlife (Decker and Gavin 1987, Stout et al. 1993, Wittman et al. 1998, Loker et al. 1999, Manfredo et al. 1999, Zinn and Andelt 1999, Siemer et al. 2004*b*). For example, Loker et al. (1999) found that acceptance of lethal management actions is more closely correlated with concerns about property damage than with concerns about health and safety impacts. People who have experienced wildlife damage tend to prefer a decrease in the population of the offending animal. Those who prefer a large population decrease are more likely than others to support lethal management actions (Lauber and Knuth 1998).

Results from separate analyses of data collected in Massachusetts and New York suggest that the same relationships hold when

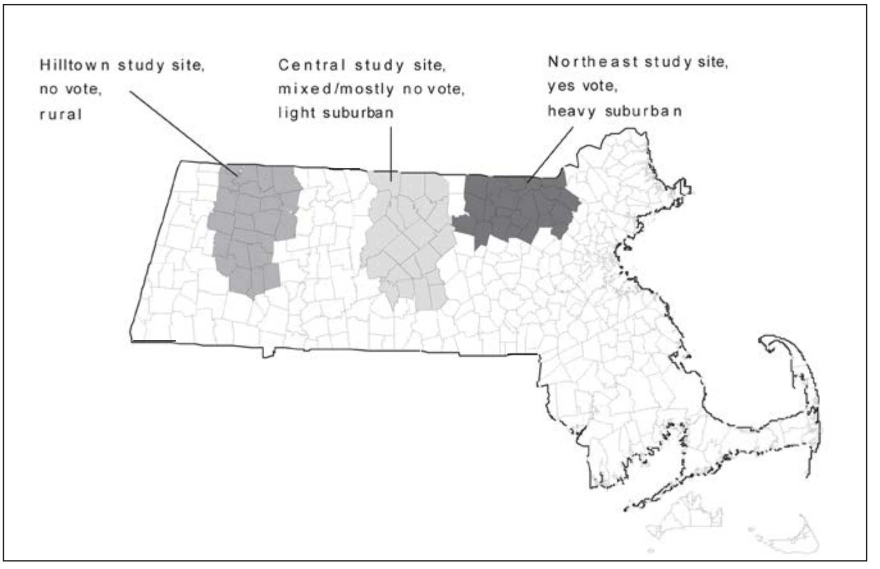

Figure 2. Study areas in Massachusetts with suburban-rural categorization and voting results of 1996 ballot initiative that proposed a prohibition of use of body-gripping traps (e.g., foothold traps, snares) to capture beavers and other furbearing animals in Massachussetts. A majority of voters in all towns in the north-eastern study site voted “yes” to ban use of all body-gripping traps. A majority of voters in all towns in the Hilltown study site voted against the initiative (i.e., voted “no”). In the central study site, some towns voted

people experience problem interactions with beavers. In both states, attitudes toward beavers were more likely to be negative among people who had experienced problems with beaver, and intensity of negative attitudes increased as the severity of problem experiences increased (Siemer et al. 2004*a,* Jonker et al. 2006). Norms about lethal management also were closely correlated with problem experience. Acceptance of lethal management tended to be higher among people who had personally experienced problems with beaver (Siemer et al. 2004*a*, Jonker et al. 2009). When presented with a range of interaction scenarios, people who had experienced beaver damage were more likely to accept lethal management actions in any scenario where beavers had a negative impact on people.

We hypothesized that acceptance capacity would be lowest among people who had experienced problems associated with beaver activity. We also expected to find higher incidence of beaver-related problems in areas with high beaver density; thus, we anticipated finding less acceptance capacity for beavers in areas with the highest beaver density. We expected people who lived in low beaver-density areas and had never experienced beaver-related problems to express the highest acceptance capacity for beavers.

Methods

Study sites and sample groups

For this paper, we regrouped a subset of data from a collaborative, 2-state research project conducted in Massachusetts and New York (see Jonker 2003 and Siemer et al. 2004*a* for a complete description of study sites and methods). The primary objective of that study was to collect baseline data for a longitudinal study of attitudes both toward beavers and beaver management (Jonker et al. 2006, 2009).

We collected data in 3 study sites representing western, central, and northeastern Massachusetts (Figure 2). Two of the sites (i.e., the central and northeast) were selected because they were already the location for beaver population monitoring by MassWildlife. These study areas represent different human-demographic and geographic features. The Massachusetts study sites also represented areas of the state that exhibited different voting results on the Wildlife Protection Act ballot initiative of 1996 (Deblinger et al. 1999). The initiative passed (with a 55% yes vote) and established the Massachusetts Wildlife Protection Act, which prohibited the use of body-gripping traps (e.g., steel-jaw foothold traps, padded foothold traps, and snares) to capture beavers and other furbearing animals (Deblinger et al. 1999).

The northeastern site is heavily suburbanized;

Table 1. Characteristics of high and low beaver density areas in Massachusetts (MA) and New York (NY).

	High beaver density sites		Low beaver density sites	
Characteristic	MA northeast study area	MA central study area	NY Mohawk Valley study area	NY Taconic study area
Number of counties	2	1	8	2
Number of towns	18	18	31	13
Human density (people/km^2 [2000])	336/km^2	64/km^2	74/km^2	37/km^2
Beaver Density (2001) (active colonies/km^2)	High (0.70)	High (0.83)	Low (0.15)	Low (0.25)
Classification	Heavy suburban	Light suburban	Light suburban	Light suburban

the central site is lightly suburbanized. At the time that the survey data were collected, both the northeastern and central areas had high beaver densities (MassWildlife estimated the densities to be 0.70 and 0.83 colonies/km^2, respectively). No estimate for beaver density was available for the western Massachusetts study site; data from respondents in that stratum were excluded from this analysis.

We selected 2 study sites in eastern New York (Figure 3) that had human population densities comparable to the sites selected by Jonker (2003) in central and western Massachusetts (Table 1). One study site was located in the Northern Taconic Aggregated Wildlife Management Unit. The second New York study site was located in the Mohawk Valley Aggregated Wildlife Management Unit. Both the Taconic and Mohawk study sites had low beaver densities at the time survey data were collected. In early 2002, NYSDEC estimated the densities to be 0.25 and 0.15 colonies/km^2, respectively (Siemer 2004*a*).

In both states we included a sample of private individuals who had reported a beaver-damage complaint to the state wildlife agency during 1999 to 2000 (i.e., the most recent years for which damage complainant records were available in both states). Complaint records from sources such as municipalities, railroads, highway superintendants, or departments of public works were excluded from the samples. We included nuisance complainants in the study because they are a stakeholder group about which wildlife managers want more information and because they can serve as a comparison group for respondents in the geographic strata.

We created 2 comparison groups based on beaver density within study sites. We combined respondents from both study areas in New York into a low beaver-density (LBD) group. We placed respondents from 2 study areas in Massachusetts in a high beaver density (HBD) group. Respondents from 2 statewide samples of beaver damage complainants were retained in the analysis as comparison groups. We used chi-square tests to assess differences between groups. Differences were reported at the $P < 0.05$ level of significance.

2002 mail survey

We collected data using a self-administered mailback questionnaire. We pretested the survey instrument during January to February 2002. We developed a final instrument based on feedback from the pretest. Following a modified Dillman (2000) method, we mailed the questionnaire, along with a cover letter and a postage-paid return envelope, to 5,563 residents in Massachusetts and 2,400 residents in New York on April 1, 2002. Nonrespondents were sent up to 3 follow-up mailings (i.e., a thank you, reminder letter, a reminder letter with replacement questionnaire, and a final reminder letter). Each mailing contained instructions asking that the questionnaire be completed by an adult in the targeted household with the most recent birthday, a device that helps ensure that both women and men respond to the survey. These surveys were completed under Human Subject Review exemptions by the University of Massachusetts and Cornell University for confidential mail-back surveys and questionnaires of this type.

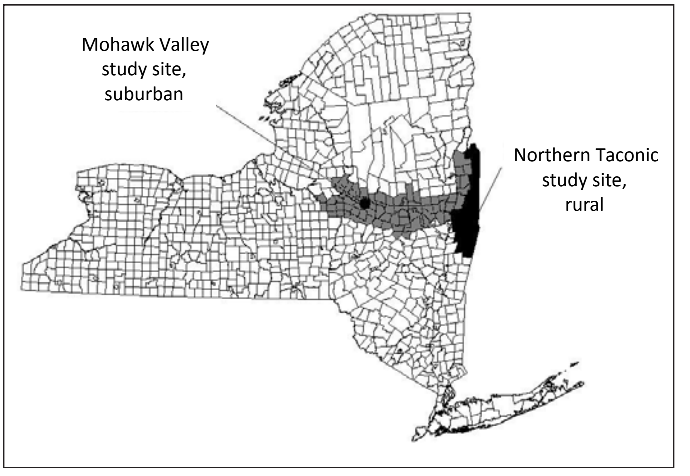

Figure 3. Study areas in New York State with suburban/rural categorization.

We developed a brief telephone version of the survey instrument to assess potential non-response bias. We completed 100 follow-up interviews with nonrespondents in each state. We requested that the adult in the household who had the most recent birthday complete the 5-minute telephone interview. The complainant strata were excluded from the follow-up study because response rates for those strata were >70%.

We detected some differences in each state when nonrespondents were compared to respondents (for a detailed description of respondent-nonrespondent comparisons, see Jonker 2003 and Siemer et al. 2004*a*). Although we found differences between respondents and nonrespondents, we decided not to adjust the data to account for potential nonresponse bias. We used sampling strategies that would allow for hypothesis testing, not generalizations about the prevalence of any given attitude, norm, or experience in a given geographic area. We anticipated low response rates from the general public samples (given that the topic of beaver management was expected to have low salience for many people) and we oversampled to ensure that we would have adequate numbers of respondents to conduct intergroup comparisons.

Measurement and analysis

Attitudes. The survey instrument contained 9 attitude statements designed to explore tolerance for beaver presence. Respondents were asked to report their agreement with attitude statements on a 5-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). The items loaded onto 2 factors, which we labeled as tolerance and intolerance. The 5 items in the tolerance attitude scale were: "In the area where I live: beaver have a right to exist; beaver are a sign of a healthy environment; beaver populations should be left alone; no beaver should be destroyed;" and "residents should learn to live with some conflicts with beaver." The 4 items in the intolerance scale were: "In the area where I live: beaver are a nuisance; beaver populations should be controlled; people don't want a wetland near their home because it could become a haven for beaver;" and "the presence of beaver makes it a burden to have a wetland near your home." We tested these scales for reliability and the items loaded adequately on each scale (tolerance scale Cronbach's alpha = 0.83; intolerance scale Cronbach's alpha = 0.82).

Effects and impacts of beavers. A wide range of positive and negative effects are produced through interactions between beavers and people. Some effects, such as the creation of beaver ponds, are easily recognized and well-known to most stakeholders. Other effects are more difficult to recognize and may go unnoticed by stakeholders. We included a set of questionnaire items to assess whether respondents recognized that beavers can create 4 different categories of effects: ecological benefits, existence benefits, economic costs, and human health risks. We also asked respondents if they believed any of these effects were

Table 2. Comparison of respondents' belief of extent of beaver damage and wildlife acceptance capacity between high and low beaver density sites and between beaver complainants in Massachusetts (MA) and New York (NY).

Variable	Group	N	$\bar{x}$	SD	t	P
Belief of extent of beaver damage[1]	HBD sites[2]	993	1.77	0.862	-15.11	<0.001
	LBD sites[3]	332	2.62	0.956		
	MA complainants	476	1.27	0.678	-10.69	<0.001
	NY complainants	370	1.88	0.966		
Wildlife acceptance capacity[4]	HBD sites	1,184	4.37	1.484	-9.76	<0.001
	LBD sites	553	5.11	1.425		
	MA complainants	480	3.22	1.555	-4.87	<0.001
	NY complainants	425	3.70	1.423		

[1]Variable coded on 5-point scale: 1 = greatly increased, 3 = remained the same, 5 = greatly decreased.
[2]High beaver density sites.
[3]Low beaver density sites.
[4]Variable coded on a 9-point scale from 1 = no beavers, 3 = 1/2 as many beavers, 5 = current number of beavers, 7 = 50% more beavers, 9 = at least twice as many beavers.

important enough to warrant management attention by NYSDEC and MassWildlife. That subset of effects that are recognized by stakeholders and regarded as being important can be defined as impacts (Riley et al. 2003). Assessing what stakeholders regard as impacts can help furbearer managers identify priorities for management attention in a given location.

Recognition of effects was measured with single-item ratings on 5-point bipolar scales anchored by strongly agree (1) and strongly disagree (5). Perceptions that a given impact was important enough to address through management were measured on the same 5-point bipolar scales (anchored by strongly agree [1] and strongly disagree [5]).

Trend in beaver damage. We used an item with 5 response options to assess respondents' perception of the trend in beaver-related damage statewide over 5 years (where 1 = greatly increased, 2 = slightly increased, 3 = remained the same, 4 = slightly decreased, and 5 = greatly decreased). We measured wildlife acceptance capacity (preferred change in beaver population level; Decker and Purdy 1988) using an item with 9 response options (1 = no beavers; 3 = 1/2 as many beavers; 5 = current number of beavers; 7 = 50% more beavers; 9 = at least twice as many beavers). For this study, a preference for a reduction in beaver population was defined as intolerance of beaver problems (i.e., preference for a population reduction indicated that acceptance capacity had been exceeded).

Normative beliefs. Normative beliefs were measured as beliefs about the acceptability of certain management actions toward beavers in different situations. Respondents were asked to respond to 4 levels of incident extremity (severity of an encounter with beavers from least severe to most severe): (1) "a beaver seen in my yard;" (2) "a beaver floods a public road;" (3) "a beaver damages my private property (trees, well, etc.);" and (4) "a beaver carries a disease that is harmful to humans." For each level of incident extremity, respondents rated the acceptability of 3 levels of management response: (1) taking no immediate action, (2) installing drainage pipes to control water levels behind a beaver dam, and (3) lethal control of beavers. Acceptability was measured with single-item ratings on 5-point bipolar scales anchored by strongly agree (+2) and strongly disagree (-2). Central tendency for norms about these management preferences are depicted using the modified Jackson Return Potential model (Jackson 1965). Differences among groups were examined using independent t-tests and ANOVA. Differences were reported at the 0.05 level of significance.

Depicting beaver management in a causal feedback loop diagram

We used Vensim software (Ventana Systems, Inc. 2004) to create a causal loop diagram depicting a beaver management system that includes common management practices and

Table 3. Comparison of respondent attitudes toward beaver between high and low beaver density sites and between beaver complainants in Massachusetts (MA) and New York (NY). An intolerance scale was created with 4 items: beavers are a nuisance; beaver populations should be controlled; people don't want a wetland near their home because it could become a haven for beavers; and the presence of beavers makes it a burden to have a wetland near your home.

Variable	Group	*N*	$\bar{x}$	SD	*t*	*P*
Tolerance attitude scale[1]	HBD sites[2]	1,113	2.71	0.816	7.95	<0.001
	LBD sites[3]	484	2.36	0.769		
	MA complainants	424	3.47	0.850	4.83	<0.001
	NY complainants	385	3.19	0.792		
Intolerance attitude scale[4]	HBD sites	1,067	2.73	0.885	-8.66	<0.001
	LBD sites	473	3.15	0.840		
	MA complainants	435	1.94	0.842	-3.88	<0.001
	NY complainants	396	2.16	0.818		

[1]Variable coded on a 5-point scale from strongly agree (1) to neutral (3) to strongly disagree (5). A tolerance scale was created with 5 items: beavers have a right to exist; beavers are a sign of a healthy environment; beaver populations should be left alone; no beaver should be destroyed; and residents should learn to live with some conflicts with beavers.
[2]High beaver density sites (HBD).
[3]Low beaver density sites (LBD).
[4]Variable coded on a 5-point scale from strongly agree (1) to neutral (3) to strongly disagree (5).

the interrelationship of those practices and stakeholder experiences, attitudes, and norms. In a causal loop diagram, balancing feedback loops (typically labeled with the letter B) counteract change in a system. The arrows in a causal loop diagram (Figure 7) designate how the authors believe 1 variable influences another. A plus sign near the arrow tip indicates that an increase in variable X leads to an increase in variable Y. A minus sign near the arrow tip indicates that an increase in variable X leads to a decrease in variable Y. For a complete description of causal feedback loop diagrams, see Sterman (2000).

Results

The adjusted response rate for the statewide samples of beaver damage complainants in New York and Massachusetts was 76.7 and 73.6%, respectively. The adjusted response rates were 38.1 and 43.5% for the LBD and HBD groups, respectively.

Perception of beaver damage and wildlife acceptance capacity

Sixty-one percent of respondents in the HBD group perceived a statewide increase in beaver damage over the previous 5 years. Only 24% of respondents in the LBD group perceived that beaver damage had increased. Respondents in the LBD were more likely to express uncertainty about beaver damage change (51% of LBD respondents checked the no-opinion response option, as compared to 17% of HBD respondents).

The same pattern was expressed when respondents who responded "no opinion" were excluded from the analysis (Table 2). That is, HBD respondents were more likely than LBD respondents to believe beaver damage had increased. A majority of respondents from the beaver complainant samples perceived that beaver damage had increased over that time period (Table 2). However, respondents in the HBD group were more likely than their counterparts in New York to perceive a great increase in the amount of beaver damage (93% versus 64%, respectively).

The proportion of respondents who had personally experienced a beaver-related problem was higher in the HBD group than in the LBD group (22.2% versus 16.4%, respectively; $\chi^2 = 8.17$; df = 1; $P = 0.004$). Nearly all respondents in the damage complainant samples had experienced a beaver-related problem; a few people on these lists had

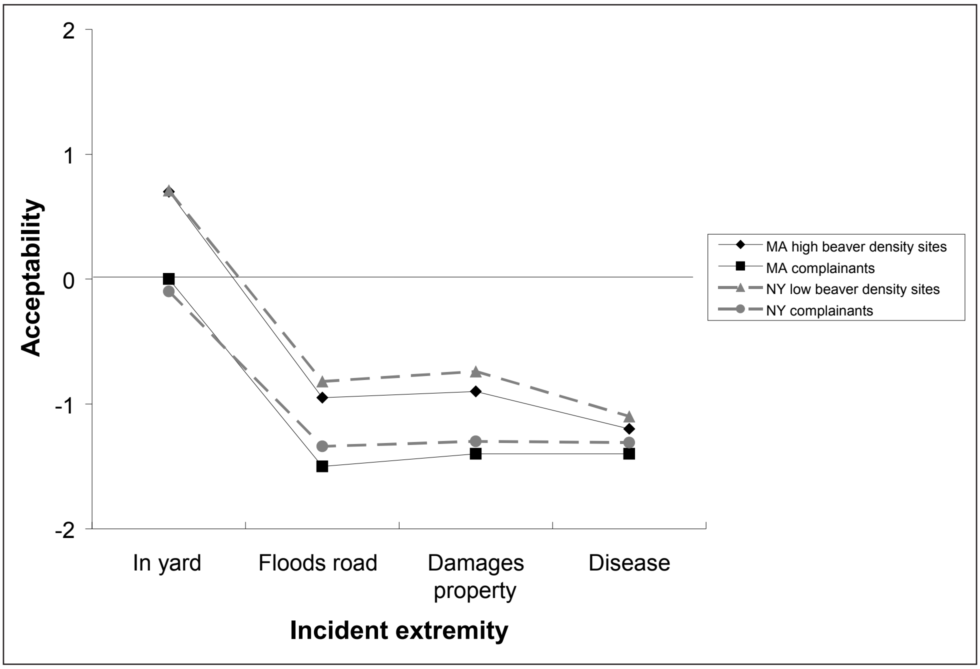

Figure 4. Acceptability of taking no action toward beavers among residents of high and low beaver density sites and among beaver complainants in Massachusetts and New York. Responses report personal acceptability of "taking no management action" in 4 situations: if a beaver (1) is seen in my yard, (2) floods a public road, (3) damages public property, or 4) carries a disease that is harmful to humans (x-axis). Response options were offered on a 5-point scale ranging from strongly agree (2) to strongly disagree (-2; y-axis).

contacted their wildlife agency for information rather than file a nuisance beaver complaint. Respondents in the complainant samples reported experiencing more severe beaver-related damage than respondents in the LBD or HBD samples. Complainants in Massachusetts reported more severe beaver-related problems than did complainants in New York.

Differences in perception of the trend in beaver damage over the past 5 years (measured on a 5-point scale from greatly increased [1] to greatly decreased [5]) were most pronounced among respondents who had experienced beaver-related problems. However, even among respondents who had never experienced such problems, HBD respondents were more likely than LBD respondents to believe that beaver damage had greatly increased ($\bar{x}$ = 1.88, SD = 0.858 for HBD; $\bar{x}$ = 2.71, SD = 0.851 for LBD; df = 973, t = -13.08, P < 0.01).

When asked about their preference for the future beaver population level (measured on a 9-point scale from no beavers [1] to at least twice as many beavers [9]), HBD group members tended to express a preference for fewer beavers in the future ($\bar{x}$ = 4.37), whereas LBD respondents indicated a preference for about the same number of beavers ($\bar{x}$ = 5.11; Table 2). Approximately 55.5% of HDB respondents preferred a beaver population reduction, as compared to 23% of LBD respondents.

In contrast, most beaver complainants in both states expressed a preference for fewer beavers (67% in New York; 83% in Massachusetts). Massachusetts beaver complainants were more likely than New York complainants to prefer a substantial beaver population reduction (Table 2). Even among respondents who had never experienced beaver-related problems, HBD respondents were more likely than LBD respondents to prefer a beaver population reduction (beaver population preference: $\bar{x}$ = 4.58, SD = 1.449 for HBD; $\bar{x}$ = 5.22, SD = 0.851 for LBD; df = 1362, t = -7.95, P < 0.001).

Attitudes

Many respondents in both beaver density groups expressed tolerant attitudes toward beavers. For example, 52% of HBD and 58% of LBD respondents agreed or strongly agreed with the statement, "residents should learn to live with some conflicts with beaver." However,

Table 4. Recognition of beaver-related effects for high and low beaver density areas and beaver complainants in Massachusetts (MA) and New York (NY).

Attitude statement[a]	High beaver density[b]	Low beaver density[b]	t	P
Beaver created wetlands benefit other wildlife.	2.35	1.96	6.25	<0.01
Beaver damage to roads and bridges is a problem.	2.42	3.03	-8.72	<0.01
People get enjoyment from seeing beaver activity.	2.54	2.12	6.85	<0.01
Drinking water contaminated by beaver flooding exposes people to diseases.	2.74	2.93	-2.46	0.01
Attitude statement[a]	**MA Complainants[b]**	**NY Complainants[b]**	t	P
Beaver created wetlands benefit other wildlife.	2.77	2.30	5.28	<0.01
Beaver damage to roads and bridges is a problem.	1.57	2.06	-6.71	<0.01
People get enjoyment from seeing beaver activity	3.09	2.56	5.94	<0.01
Drinking water contaminated by beaver flooding exposes people to diseases	1.89	2.74	-8.32	<0.01

[a] Variables coded on a 5-point scale from strongly agree (1) to strongly disagree (5).
[b] Cell entries are means.

HBD respondents expressed slightly less agreement with tolerant attitude statements (Table 3). In contrast, respondents in the beaver complainant samples in both states tended to disagree with tolerant attitude statements about beavers, with Massachusetts complainants being more likely to disagree than the New York complainants (Table 3). Among respondents who had never experienced beaver-related problems, HBD respondents were less likely than LBD respondents to agree strongly with tolerant attitude statements (tolerance attitude scale: $\bar{x}$ = 2.60, SD = 0.789 for HBD; $\bar{x}$ = 2.28, SD = 0.714 for LBD; df = 1251, t = 6.93, P < 0.001).

HBD respondents agreed, albeit not strongly, ($\bar{x}$ = 2.77) with intolerant attitude statements, whereas, LBD respondents tended to disagree ($\bar{x}$ = 3.15) with such statements (Table 3). We observed the same pattern when comparing only respondents who had never experienced a beaver-related problem: HBD respondents were more likely than LBD respondents to agree with statements in the intolerant attitude scale (intolerant attitude scale: $\bar{x}$ = 2.87, SD = 0.862 for HBD; $\bar{x}$ = 3.26, SD = 0.755 for LBD respondents; df = 1197, t = -7.69, P < 0.001). Beaver complainants in both states agreed with the intolerant attitude statements, with Massachusetts complainants agreeing more strongly than New York complainants (Table 3).

Effects and impacts

Recognition of effects differed among comparison groups. LBD respondents were the most likely, and damage complainants were the least likely to agree that beaver-created wetlands benefit other wildlife species or that people get enjoyment from seeing beaver activity (Table 4). LBD respondents were the least likely and complainants were the most likely to agree that beaver damage to roads and bridges was an important problem (Table 4). Most respondents in all groups believed that flooding caused by beaver activity can contaminate drinking water and threaten human health. Complainants and respondents in the HBD group were most likely to strongly agree that beaver flooding can threaten human health (Table 4).

Recognition of impacts also differed by group. HBD respondents were less likely than LDB respondents to agree that wildlife management should focus on increasing beneficial effects associated with beaver activity

Table 5. Recognition of beaver-related impacts for high and low beaver density areas and beaver complainants in Massachusetts (MA) and New York (NY).

Attitude statement[a] ("Wildlife managers should attempt to . . .")	High beaver density[b]	Low beaver density[b]	*t*	*P*
Maintain beaver created wetlands as a means to benefit other wildlife.	2.63	2.30	5.20	<0.01
Reduce the cost of beaver damage to roads and bridges.	2.12	2.59	-7.44	<0.01
Create opportunities for the public to see beaver activity.	2.94	2.50	6.95	<0.01
Ensure that beaver flooding does not contaminate drinking water.	1.62	1.88	-5.08	<0.01

Attitude statement[a] ("Wildlife managers should attempt to . . .")	MA Complain-ants[b]	NY Complainants[b]	*t*	*P*
Maintain beaver created wetlands as a means to benefit other wildlife.	3.36	2.87	5.24	<0.01
Reduce the cost of beaver damage to roads and bridges.	1.67	2.02	-4.60	<0.01
Create opportunities for the public to see beaver activity.	3.59	3.10	5.43	<0.01
Ensure that beaver flooding does not contaminate drinking water.	1.32	1.64	-5.23	<0.01

[a] Variables coded on a 5-point scale from "strongly agree" (1) to "strongly disagree" (5).
[b] Cell entries are means.

(e.g., creating wetlands habitat or wildlife viewing opportunities). Complainants were the least likely to agree that wildlife managers should manage for beneficial effects produced by beaver activity (Table 5). Complainants were more likely than other respondents to agree that the cost of beaver damage to roads and bridges was an effect important enough to be the focus of management attention (Table 5). Most respondents in all groups believed that preventing contamination of drinking water should be a management priority. Complainants in Massachusetts were most likely to strongly agree that this should be a management priority (Table 5).

Norms

Most respondents in both beaver density groups agreed that it was acceptable to take no action when a beaver was in the least severe situation presented (i.e., a situation where the beaver is simply observed in one's backyard). However, respondents in both beaver density groups tended to find it unacceptable to take no action when a beaver was having any type of negative impact on people. Complainants found it unacceptable to take no management actions under any scenario that involved negative effects on people. Many complainants found it unacceptable for managers to remain inactive even in a scenario where negative effects had not yet occurred (Figure 4).

With respect to the acceptability of installing water flow devices in response to beaver activity, respondents in both beaver density groups disagreed that it was justified to install these devices when a beaver was "seen in my backyard." However, as the severity of the incident increased to "floods a public road," respondents in both the LBD and HBD groups consistently agreed that it was acceptable to install water flow devices. The degree of acceptability did not increase as the severity of the incident increased; in fact, it decreased and fluctuated, with HBD respondents consistently agreeing more than LBD respondents that this management action is justified. Complainants did not differ from HBD or LBD groups with respect to the acceptability of installing water flow devices (Figure 5).

With respect to the acceptability of using lethal control in response to beaver incidents,

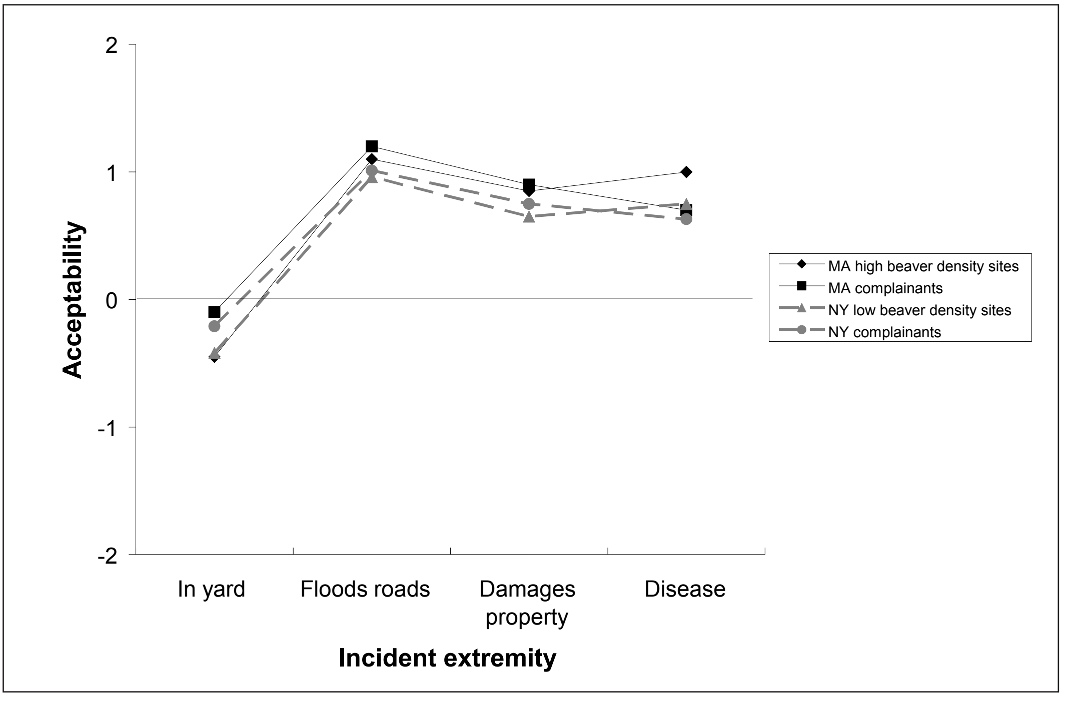

Figure 5. Acceptability of altering beaver dams (controlling water level behind beaver dams) among residents of high and low beaver-density sites and among beaver complainants in Massachusetts and New York. Responses report personal acceptability of "installing drainage pipes to control water levels behind a dam" in 4 situations: if a beaver (1) is seen in my yard; (2) floods a public road; (3) damages public property; or (4) carries a disease that is harmful to humans (x-axis). Response options were offered on a 5-point scale, ranging from strongly agree (2) to strongly disagree (-2; y-axis).

respondents in both beaver density groups found it unacceptable to use this method when a beaver is "seen in my yard." LBD respondents tended to find use of lethal control unacceptable as a response to "floods a public road," or "damages my private property," but HBD respondents tended to find lethal management acceptable in those scenarios. Both beaver density groups found lethal action acceptable when the scenario was "carries a disease that is harmful to humans" (i.e., there was no difference between HBD and LBD groups with regard to norms on use of lethal control when human health was at issue). Beaver complainants in both states were more likely than the low or high beaver density subgroups to find use of lethal control actions acceptable as a response to any of the presented scenarios (Figure 6).

Discussion

The results of our analysis support the hypotheses described earlier. We found support for expected relationships among beaver density, beaver-related problem experience, attitudes toward beavers, and norms about beaver management actions. Our findings suggest that high beaver densities may create negative impacts that lead to lower acceptance capacity for beavers. In addition, we found that acceptance of lethal management actions increases as the severity of beaver damage (i.e., incident extremity) increases. Given these findings, managers should expect stakeholder tolerance for beavers to decline as the prevalence and severity of beaver-related problems increase in a community.

Though some important differences were discovered, we also found many similarities across groups with respect to norms toward beaver management. After respondents personally experienced any negative impact from beaver activity, regardless of where they were, they were more likely to accept some form of beaver management. Influence of central values may help explain such similarities in norms. We took steps to measure wildlife value orientation and attitudes toward protection or management of beavers as a pest species.

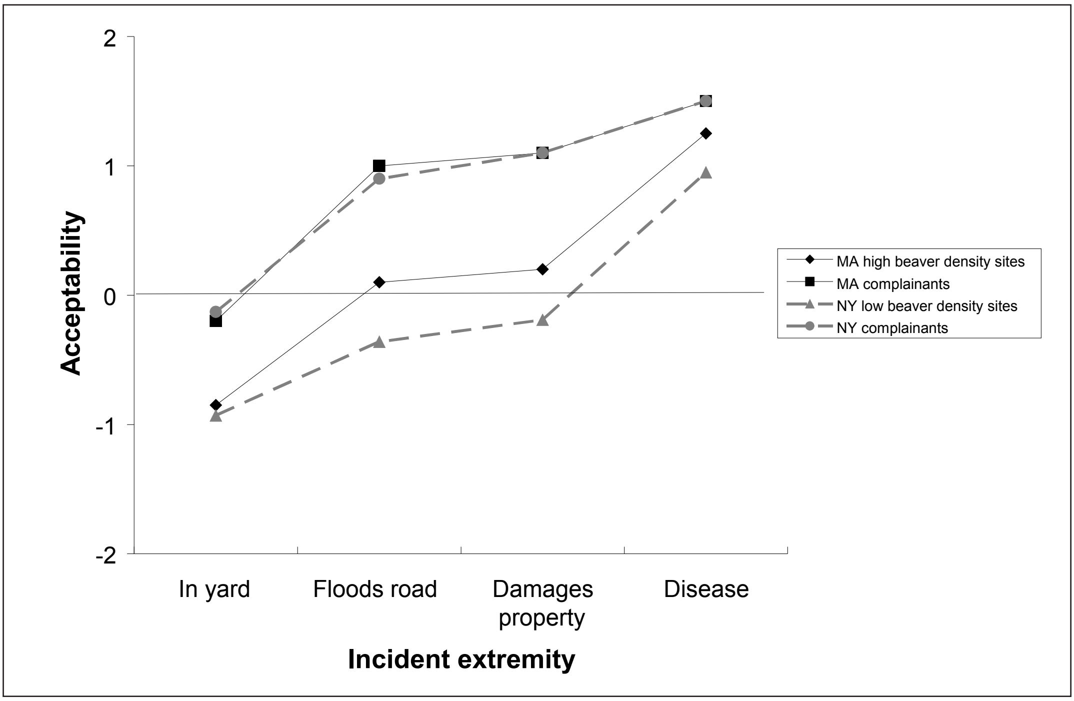

Figure 6. Acceptability of lethal control of beaver among residents of high and low beaver-density sites and among beaver complainants in Massachusetts and New York. Responses report personal acceptability of "lethal control of beavers" in 4 situations, if a beaver: (1) is seen in my yard; (2) floods a public road; (3) damages public property; or (4) carries a disease that is harmful to humans (x-axis). Response options were offered on a 5-point scale ranging from strongly agree (2) to strongly disagree (-2; y-axis).

However, we did not examine central values related to things, such as personal health and economic security. These very basic concerns may trump higher order attitudes and norms related to a specific species of wildlife. It may well be that consistency in responses across different beaver density groups are a function of some shared central values that we did not measure in our study.

The differences we observed between the LBD and HBD groups are consistent with the higher level of beaver-related problems experienced by the HBD group. But many of those differences also appeared among respondents who had never experienced a problem with beavers. These patterns among people who have never experienced a problem are plausible if we assume that beliefs, attitudes, and norms toward wildlife can be influenced indirectly, through interpersonal and mass communication. HBD residents lived in Massachusetts, where unprecedented growth in beaver populations had transpired in the years preceding our mail survey (beaver population increase was already occurring in the early 1990s and, then, accelerated after passage of the Wildlife Protection Act in 1996 that restricted trapping). The problems associated with beaver population increase were a subject of regular media attention in Massachusetts, and it is reasonable to assume that such coverage influenced beliefs and attitudes toward beavers and beaver management. Wildlife agencies should consider how media coverage of beaver management issues might offer them a forum for education about problem prevention. Stakeholders who have not yet experienced problems may be an especially important audience for those communication efforts.

A model of the beaver management system that clarifies implications for management

Our findings on the relationship between beaver population density and attitudes about beaver management are noteworthy because they have important implications for beaver management. In coming years, managers are likely to witness more situations where beaver density is high, and more stakeholders

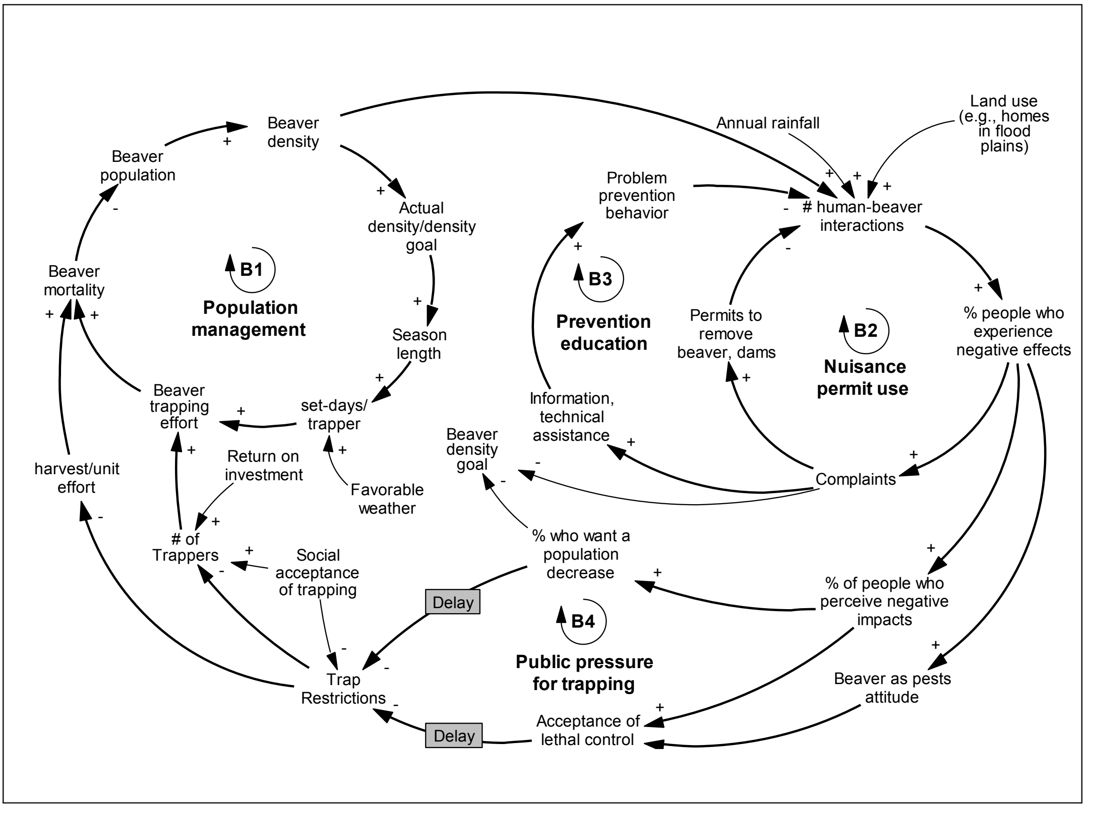

Figure 7. Causal loop diagram of beaver management, supported by literature review and comparative research in areas with different beaver densities. Arrows designate how the authors believe 1 variable influences another. A plus sign near the arrow tip indicates that an increase in variable X leads to an increase in variable Y; a minus sign indicates that an increase in variable X leads to a decrease in variable Y. The diagram contains 4 balancing loops (labeled B1 to B4). Natural increase in beaver density and human–beaver interactions is counteracted by balancing loops labeled: population management (B1), nuisance permit use (B2), prevention education (B3), and public pressure for trapping (B4).

are experiencing beaver-related problems. Effective response to these situations will become increasingly important for wildlife management agencies.

To better understand and describe the implications of our analysis, we created a causal loop diagram (Figure 7) depicting a beaver management system that includes common management practices and the interrelationship of those practices and stakeholder experiences, attitudes, and norms. Most of the diagram depicts how wildlife managers use 3 practices to reduce negative human–beaver interactions and the negative impacts created by such interactions: beaver population management; beaver and beaver dam removal permits; and damage prevention education. These approaches are well-known. What we add to this understanding is a depiction of how stakeholders exert an influence on the typical beaver management system as beaver density increases. To our knowledge, the feedbacks and delays described in Figure 7 have not been well-described in the wildlife management literature.

Our depiction of the beaver management system contains 4 balancing loops (labeled B1 to B4). In this instance, a natural increase in beaver density and human-beaver interactions is counteracted by balancing loops labeled: population management (B1), nuisance permit use (B2), prevention education (B3), and public pressure for trapping (B4). The following text describes linkages in each feedback loop. In each section, we discuss the implications for beaver management if these balancing feedback loops are removed from the beaver management system.

Population management loop (B1)

Over the past century, the focus of beaver management has shifted from species recovery to relief from problems associated with beaver activity. Wildlife managers have relied primarily on regulated beaver trapping to achieve reductions in human–beaver interactions and the problems that can result from those interactions.

A typical beaver population management cycle includes the key variables shown in Figure 7, loop B1 (Population management). As a beaver population increases, density of beavers (e.g., colonies/km^2) increases. In some jurisdictions, managers assess or estimate beaver density annually. If the actual density of beavers exceeds the density goal in a given region, managers will liberalize the beaver trapping season. Lengthening the trapping season allows trappers to set more traps or other trapping devices (e.g., cable restraints, snares) on more days. Increasing the season length, thus, leads to greater trapping effort and greater beaver mortality. Removal of beavers lowers the beaver density and reduces the gap between the actual beaver density and beaver-density goal.

Management concerns. Wildlife managers consider regulated trapping to be the most efficient and effective means of beaver population control (Miller 1983, Boggess et al. 1990, Bishop et al. 1992, Conover 2001), and most state wildlife agencies regard beaver population control as a means to keep beaver-related property damage within acceptable levels. But trapping effort may be suppressed under a variety of conditions. If social acceptance of trapping falls, trapping restrictions or prohibitions may be established. During the 1990s, several states (e.g., Arizona, California, Colorado, Massachusetts) passed ballot initiatives that banned the practice of trapping furbearer animals or prohibited use of foothold or body-gripping traps. These restrictions limit managers' ability to control beaver populations by reducing trapper participation or by reducing beaver harvest per unit effort. Events in Massachusetts might be interpreted as evidence of the dynamic feedback loops that influence beaver population control. Attrition of trappers was occurring in Massachusetts even before the 1996 legislation that restricted trap use. Restricting trappers (e.g., to the use of box traps) has created a set of disincentives to participate in beaver trapping that are likely to keep trapping involvement at a low level. In the 5 years following passage of the 1996 Massachusetts Wildlife Protection Act, the beaver population increased from approximately 24,000 to >70,000 (MassWildlife 2012). The state wildlife management agency no longer has the ability to influence beaver numbers through regulated fur trapping.

In a given year, participation in trapping also may decline due to an actual or perceived poor return on investment (e.g., low beaver pelt prices in the previous 2 years or high gas prices [Runge 1999]), weather conditions during the trapping season (Runge 1999), or because of declining recruitment and retention of trappers. Declining trapper recruitment, a national trend accelerated by low social acceptance of trapping among the nontrapping public, has been of particular concern in the northeastern United States (Organ et al. 1998). Any conditions that reduce beaver trapping effort reduce managers' ability to reduce negative human–beaver interactions via loop B1. Suppressing loop B1 lowers the beaver mortality rate, allowing for rapid increases in the number of beavers and the density of beaver colonies in specific locales.

Public pressure for trapping (B4)

Public pressure for trapping loop (B4) is comprised of variables connected in a clockwise fashion around the perimeter of the causal loop diagram. The connections in this loop are as follows. As beaver density increases, human–beaver interactions increase. In addition to beaver density, we assume that human–beaver interactions tend to increase as a function of 2 factors over which managers have no control: amount of rainfall and land development of private lands in flood plains. Greater interaction produces more negative effects for people, some of which stakeholders regard as impacts (i.e., effects important enough to warrant the attention of the wildlife management agency). As more stakeholders personally experience beaver-related problems, the proportion of area residents who desire a beaver population reduction and the proportion who accept lethal beaver management approaches both increase (i.e., residents in high beaver density areas will become more likely to ask for management intervention focused on control of problems, rather than management intervention to obtain the benefits beavers may provide to a community).

These changes in stakeholder attitudes and norms can eventually contribute to liberalization of trap restrictions in states where such restrictions exist. Liberalization of trap restrictions can lead to greater trapper involvement and increased beaver harvest per unit effort. Both of those changes contribute to increasing trapping effort, higher beaver mortality rate, and a decrease in the beaver population.

Management concerns. There is a significant time delay between change in attitudes or norms and a corresponding change in trap restrictions. In Figure 7, causal loops B1, B2, and B3 can go through a complete cycle in a single year. The kind of social pressure depicted in causal loop B4 may operate on a time scale of several years or even decades. In Massachusetts, for example, trap restrictions have been imposed and then revised or eliminated a few years or a few decades later (Deblinger et al. 1999). There are social costs associated with those delays (e.g., community disruption, social tension, loss of landscape features important to private landowners). Moreover, in cases where trapping restrictions are in place for years, trapper recruitment and retention can be expected to decline markedly. By the time trapping opportunities are restored, the pool of potential trappers may be too low to effectively control beaver populations.

Nuisance permit use loop (B2)

Managers also have attempted to reduce problem incidence through permitting processes that allow for removal of beavers or beaver dams. This policy path is depicted by loop B2. As more people experience negative interactions with beavers, the proportion of people who experience negative effects increases. That leads to an increase in complaints to the wildlife management agency. The agency responds by granting more permits to remove beavers or beaver dams.

Management concerns. The nuisance permit loop becomes the dominant loop under conditions where regulated trapping is not permitted or is of low interest to trappers. For example, in southern states, nuisance control permits are the primary management tool because beaver pelts have low value (Bhat 1993). Most states grant nuisance permits to individual landowners or businesses on a case-by-case basis. In Massachussetts, local boards of health have been given authority to issue emergency permits that allow individuals to trap and remove beavers that are deemed to present a risk to public health (MassWildlife 2012). Though such permits may provide individuals with relief from local beaver-related problems, they represent an uncoordinated approach to beaver removal that has little effect on beaver population growth or beaver densities at a landscape level.

In the absence of regulated trapping, managers in the northeastern United States would need to consider revisions to their policies such that loop B2 would operate at a landscape level. One means of doing so would involve granting beaver- removal permits to landowner cooperatives that execute their permit across the landscape under a coordinated management plan. There are likely to be barriers to creating landowner cooperatives for beaver management. Wildlife agencies could serve a useful role in beaver management by identifying and reducing those barriers. However, some agencies may be reluctant to encourage a management system that relies heavily on landowner collectives to remove nuisance beavers.

A management system that relies heavily on nuisance removal permits has the potential to devolve into a pest management system. Managing beavers as a pest species in the Northeast would likely involve a system of paid nuisance wildlife control trappers. Municipalities might contract with private vendors to remove nuisance beavers much as they now contract with private vendors to conduct waste management. One could envision a path toward widespread privatization of damage management services in residential areas where beaver habitat is available. Such privatization raises larger philosophical concerns about the management of wildlife as a public trust resource and brings into question the conservation paradigm that drives the management of our natural resources (Organ and Batcheller 2009).

Prevention education loop (B3)

Providing information or technical assistance is a common approach to managing the problem interactions and resulting complaints that arise with high densities of beavers. Loop B3 reflects the common assumption that providing information or assistance will increase problem prevention behaviors, leading to a reduction in problems and complaints.

Management concerns related to this balancing loop. If information and assistance programs are absent or ineffective, balancing loop B3 does not operate. Failure in this loop means that negative interactions and complaints will continue to mount. Even if information and assistance programs are successful, they do not directly affect beaver density. Perceived failure in education may lead to greater social pressure for beaver population reduction through lethal management actions, which will not be widely available in some states. In situations where trapping is restricted (i.e., loop B1 is ineffectual) and nuisance-removal permits are granted in an uncoordinated case-by-case basis (i.e., loop B2 is ineffectual), loop B3 would have to operate with great effectiveness to counteract the increase in human–beaver interactions that can be expected at high beaver densities. Little evidence exists to indicate that education interventions have significantly reduced incidence of beaver damage, so managers have reason to be concerned about a management system that relies heavily on prevention education.

Encouraging systems-thinking in beaver management issues

In this manuscript, we have offered a conceptual representation of key dynamic interrelationships between the human and biological dimensions of a beaver management system. We offered a concept map (Figure 7) as a mechanism to clarify the implications of our findings for practicing furbearer managers, especially those in areas where beaver densities are increasing and the future of conventional beaver trapping is in question. The feedback loops and delays described in our concept map represent an explicit set of testable assumptions that should be refined through additional research and dialogue among management practitioners.

The specific context for beaver management varies from state to state, but we argue that the main components and dynamics of beaver management portrayed in our concept map are present in nearly any location where high densities of beavers and people set the stage for human–wildlife conflict. We believe that the conceptual diagram presented here offers a tool that allows wildlife managers and stakeholders to visualize and communicate about beaver management as a coupled human-natural system with dynamic feedback and delays. Discussing these dynamics may help managers and stakeholders to build a shared understanding of the uncertainties, complexity, and feedback processes involved in managing the negative impacts of beavers in suburban areas. Developing that shared understanding is one of the key building blocks managers must establish in order to work through these disruptive wildlife management issues.

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