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Original Article

Economic Influences on Trapper Participation and Per Capita Harvest of Muskrat

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ABSTRACT Muskrat (*Ondatra zibethicus*) populations in North America appear in decline in parts of their geographic range, prompting in-depth investigations into population trends. However, long-term data on muskrat population abundance are rare and managers often rely on harvest data to track relative changes in population sizes. These data are likely biased by factors that influence trapper participation and effort and, if left unidentified and uncontrolled for, may provide misleading indices of muskrat abundance. Using 36 years (1976–2011) of detailed muskrat-harvest information from Illinois, USA, we estimated the relative importance of economic factors to trapper participation and annual per capita muskrat harvest. As expected, annual muskrat harvest was positively correlated with the number of individuals participating in muskrat trapping. Participation in muskrat trapping was associated positively with pelt and gas prices and negatively with the unemployment rate during the trapping season ($R^2 = 0.76$). Variance partitioning within our most-supported model revealed that pelt prices, independent of gasoline prices and unemployment rates, was the most important predictor of muskrat trapper participation. Our only supported model of per capita muskrat harvest indicated that gasoline prices negatively influenced the number of muskrats harvested per trapper each year ($r^2 = 0.17$). Remaining unexplained variation in this model may be due to factors affecting muskrat availability (e.g., muskrat abundance, access to good-quality trapping areas) to trappers and may be useful for managers investigating population trends. We recommend that future investigations using muskrat harvest data, at minimum, statistically adjust for the strong positive effect of pelt prices.

KEY WORDS gasoline price, harvest, Illinois, muskrat, *Ondatra zibethicus*, pelt price, trapping, unemployment rate.

Muskrats (*Ondatra zibethicus*) are widespread across North America and an economically important furbearer species (Errington 1961, 1963). Anecdotal reports and strikingly lower harvests in recent decades suggest muskrat populations are declining across parts of their geographic range (Roberts and Crimmins 2010), prompting a need for new investigations of long-term trends in population abundance. Obtaining information on muskrat abundance across large spatial scales is logistically difficult, leaving biologists to rely on harvest data (total number of pelts sold or animals harvested) to track relative changes in population size (Elton and Nicholson 1942, Erb et al. 2000, Haydon et al. 2001). These data are generally influenced by extrinsic factors (e.g., fur markets, trapper participation), which must be identified and controlled for prior to analysis of population trends (Erickson 1982, DeVink et al. 2011, McKelvey et al. 2011).

Fur harvest data should reflect both muskrat availability (e.g., species abundance, trappers' access to species habitat) and trapper effort (Erickson 1982, McKelvey et al. 2011). Thus, the utility of harvest data sets to managers depends upon quantifying the variation in annual harvests due to factors other than muskrat abundance. Although important components of all fur-harvest data sets, factors influencing trapper participation and per capita effort are poorly understood by wildlife managers (Daigle et al. 1998). Generally, annual muskrat harvest is considered strongly associated with the market value for pelts (Erickson 1982, Roberts and Crimmins 2010). Higher pelt prices are assumed to provide a greater economic incentive for individuals to participate in muskrat trapping and trappers to increase per capita harvest effort. Although this relationship is intuitively appealing, it has rarely been rigorously evaluated and other economic factors that could influence trapper participation or harvest rate have not been simultaneously assessed.

Individuals participating in muskrat trapping can incur substantial financial costs (e.g., annual licenses, traps and trap maintenance, fur preparation, travel). Fiscally oriented trappers (i.e., individuals participating in trapping because their potential financial gain outweighs annual operating costs) may engage in trapping or allocate more effort to muskrat harvesting if pelt prices are high. Similarly, high unemployment rates could indicate times when more

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individuals seek to supplement their income by trapping. Lower gas prices can be an economic incentive, but the relationship to harvest is less clear. On the one hand, higher gas prices could indicate times of economic hardship when income from trapping would be enticing. Alternatively, trappers may limit their efforts if travel costs (e.g., gas prices) are high; we expect this latter influence to be greater. For other trappers, participation is a result of tradition and personal satisfaction derived from outdoor activity, which may be less responsive to economic influences (Siemer et al. 1994, Daigle et al. 1998, Zwick et al. 2006, Schroeder and Fulton 2015).

We assessed the influence of selected economic variables (i.e., pelt prices, gas prices, unemployment rate) on trapper participation, per capita harvest, and annual muskrat harvest over 36 years (1976–2011) in Illinois, USA. If economic incentives influence trapper participation, we expect the number of individuals trapping muskrats each year in Illinois to be related positively to pelt prices and the unemployment rate, but negatively to gas prices. To increase their harvest efforts (independent of increases in muskrat abundance), muskrat trappers likely will have to extend their trapping efforts across larger areas. Therefore, we expect gas prices will be negatively related to per capita muskrat harvests. If pelt prices and unemployment rates influence harvest effort, we expect a positive association between these economic indices and per capita muskrat harvests.

STUDY AREA

Illinois is located in the midwestern United States, with a flat and rolling topography (85–380 m above sea level) and consists of large regions devoted to agriculture. Almost 75% (~11 million ha) of the land area in Illinois was allocated to farming operations. Average annual temperatures (1.6–20.6° C) and precipitation (89–122 cm) varied depending upon season and latitude. The state was characterized by high-density human populations and urban landscapes (e.g., Chicago metro area; third-largest metropolitan population in the United States) in its northeastern corner, intensive agricultural production in the central portion, and low-density human populations and rolling, forested hills in the southern third. Legal muskrat trapping was restricted to November through January across the state. Muskrat-trapping restrictions and season lengths remained relatively unchanged during the duration of the study.

METHODS

Data Collection

Licensed fur buyers in Illinois are legally required to submit information on all raw pelts purchased, including their average market values, to the Illinois Department of Natural Resources during a given harvest season. These data are compiled and summarized into annual Illinois Fur Harvest Surveys that are freely available to the public from the Illinois Department of Natural Resources upon request. From these reports (supplemented with information from the state furbearer biologist), we obtained average annual market pelt values (U.S. dollars [hereafter, $]) for muskrats in Illinois from 1976 to 2011. We obtained average annual retail gasoline prices (US$/gallon) from the Office of Energy Efficiency and Renewable Energy (www.energy.gov). Both pelt prices (median = $4.45, range = $1.69–$20.31) and gas prices (median = $2.07, range = $1.46–$3.53) were adjusted for inflation on an annual basis using the Consumer Price Index for 2011 (www.bls.gov/data/) prior to analysis. We calculated the average unemployment rate for Illinois (http://www.davemanuel.com/historical-state-unemployment-rates.php) during the extent of each trapping season (Nov, Dec, and Jan) from 1976 to 2011 (median = 6.4%, range = 4.3–13.0%).

We obtained annual estimates of the number of muskrat trappers in Illinois, and estimated annual muskrat harvests, from Illinois Trappers Surveys (1976–2011) that were conducted by the Illinois Natural History Survey. From 1977 to 2011, a randomly selected subset of license holders were sent questionnaires to assess their harvest effort and success (e.g., Alessi et al. 2012). The entire population of licensed fur trappers in Illinois ($n = 17{,}800$) was sampled in 1976. All trapper data were collected under the University of Illinois Intuitional Review Board Human Subjects permit (#10263). We estimated the total number of individuals participating in muskrat trapping in Illinois during a given year ($Trappers_t$) as

$$Trappers_t = \frac{L_t}{n_t} MR_t$$

where L_t = number of licensed trappers during year t; n_t = number of respondents to the Illinois Trapper Survey during year t; and MR_t = number of respondents who participated in muskrat trapping during year t.

We estimated the state-wide annual muskrat harvest ($Harvest_t$) as

$$Harvest_t = \frac{L_t}{n_t} HR_t$$

where HR_t = total muskrat harvest reported by respondents. Our annual estimate of per capita muskrat harvest was then derived as

$$\frac{Harvest_t}{Trappers_t}$$

Data Analysis

We used generalized linear models (PROC GENMOD; SAS® v 9.4, SAS Institute, Inc., Cary, NC, USA) to investigate general trends in muskrat harvest and trapper participation. To account for the large range of values across years, we transformed our response variables (i.e., estimated number of muskrats harvested and estimated number of muskrat trappers during a given year) using a natural-log transformation prior to all analyses. Additionally, we used generalized linear models to test hypotheses relating the number of individuals participating in muskrat trapping and per capita muskrat harvest to pelt prices, gas prices, and unemployment rates.

We constructed a candidate set of models for both muskrat trapper participation and per capita muskrat harvest in Illinois. For each candidate set, we investigated support for 8 competing models using Akaike's Information Criterion, adjusted for small sample sizes (AIC_c; Burnham and Anderson 2002, Arnold 2010). We evaluated 3 models investigating single effects of our covariates (i.e., Pelt Price, Unemployment Rate, Gas Price) and 4 models investigating combinations of additive effects (Pelt Price + Gas Price, Pelt Price + Unemployment Rate, Gas Price + Unemployment Rate, Pelt Price + Gas Price + Unemployment Rate). We also included a constant model (*Intercept Only*) in each candidate set. There was minimal collinearity between covariates included in the same model (Pearson Correlation < 0.50). Models with $\Delta AIC_c \leq 2.00$ were considered competitive (Burnham and Anderson 2002). To evaluate the amount of variation explained by our most-supported models, we used a pseudo-R^2 (1 – [deviance of model of interest/deviance of constant model]).

To understand how much variation in our most-supported model of trapper participation was explained by the pure effect of each covariate (not influenced by collinearity with other effects included in the model) and the amount of variation attributed to their shared effects, we used a variation partitioning analysis (Seibold and McPhee 1979, Legendre 1998). The variation explained solely by the pure effect of an individual covariate, *i*, (P_i) in a 3-factor model was estimated as

$$P_i = R^2_{i+x+j} - R^2_{x+j}$$

where R^2_{i+x+j} = pseudo-R^2 of the 3-factor model including covariates *i*, *x*, and *j*; R^2_{x+j} = pseudo-R^2 of an additive model excluding covariate *i*.

We estimated the amount of variation explained by the 3-factor model attributed to the shared effects of 2 covariates, *i* and *x*, (S_{i+x}) as

$$S_{i+x} = \left(R^2_{i+j} + R^2_{x+j} - R^2_j\right) - R^2_{i+x+j}$$

Variation attributed to the overlaid effects of all 3 covariates (*i*, *x*, *j*) was expressed as

$$\left(R^2_i + R^2_x + R^2_j\right) - \left(R^2_{i+x} - R^2_{i+j} - R^2_{x+j}\right) + R^2_{i+x+j}$$

A more detailed explanation of these derivations is fully described in Seibold and McPhee (1979).

RESULTS

From 1976 to 2011, the Illinois Natural History Survey delivered 61,000 surveys (median = 1,200, range = 665–17,800) to licensed trappers with an average response rate of 75% (SD = 11.35). During this period trappers harvested an estimated 5,347,013 muskrats (median = 67,519, range = 22,677–564,497) and numbers of individuals participating in muskrat trapping varied across annual trapping seasons (median = 1,839; range = 801–14,833). Both participation in muskrat trapping ($\beta = -0.08$, SE = 0.01, $F_{1,35} = 116.13$, $P < 0.001$; Fig. 1A) and estimated annual muskrat harvest ($\beta = -0.08$, SE = 0.01, $F_{1,35} = 123.07$, $P < 0.001$; Fig. 1B) declined noticeably across years. As expected, trapper participation correlated positively with estimated muskrat harvest ($r = 0.97$, $P < 0.001$). In contrast, per capita muskrat harvest did not decline during this period ($\beta = -0.03$, SE = 0.10, $F_{1,35} = 0.08$, $P = 0.78$; Fig. 1C) and was unrelated to estimated annual harvest ($r = 0.12$, $P = 0.46$).

Our highest-ranked model indicated that pelt price ($\beta = 0.15$, SE = 0.02, 95% CI = 0.12–0.18), gas price ($\beta = -0.49$, SE = 0.17, 95% CI = −0.80 to −0.16), and unemployment rate ($\beta = 0.17$, SE = 0.04, 95% CI = 0.09–0.26)

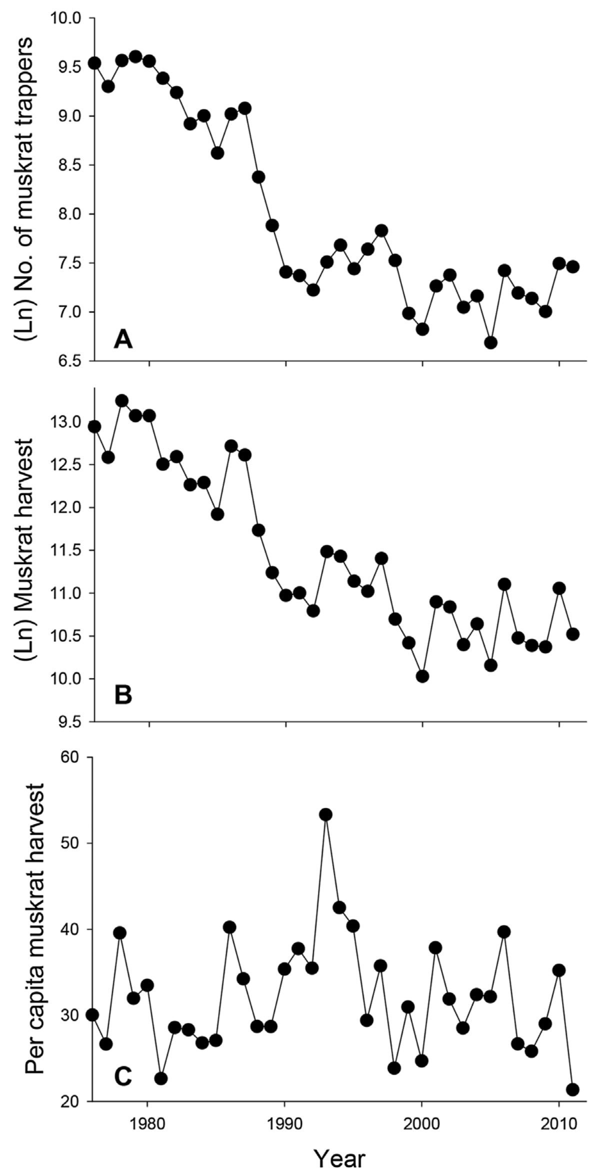

Figure 1. Long-term trends in muskrat trapper participation (A), estimated muskrat harvest (B), and per capita muskrat harvest (C) in Illinois, USA, from 1976 to 2011. Annual muskrat-trapper participation and estimates of muskrat harvest were derived from surveys sent to licensed trappers that were randomly selected at the end of each trapping season.

were each important predictors of muskrat trapper participation in Illinois ($R^2 = 0.76$, $w_i = 0.91$; Table 1). No other models were competitive. Pelt price and unemployment rate were both related positively to trapper participation (Fig. 2A and C), whereas gas price was related negatively to participation (Fig. 2B).

Pelt price (independent of gas price and unemployment rate) clearly emerged as the main factor explaining variation within our top model (64.7%; Fig. 3), while the pure influences of gas prices (5.8%) and unemployment rate (10.0%) accounted for relatively smaller percentages (Fig. 3). The amount of variation in our top model co-predicted by pelt price, gas price, and unemployment rate was 9.2%; the amount of variation explained simultaneously by the shared effects of all 2-factor combinations was negative (Fig. 3). When holding gas price and unemployment rate at their median values, our most-supported model of muskrat trapper participation predicted a 24% increase in the number of muskrat trappers for every US$2.00 increase in pelt prices.

Our only competitive model for per capita muskrat harvest indicated that gas price ($\beta = -4.53$, SE = 1.70, 95% CI = -7.86 to -1.21; Fig. 4) negatively influenced individual trapping effort ($r^2 = 0.17$, $w_i = 0.50$; Table 1). Our model predicted a 6% decrease in per capita harvest for every 0.50 cent ($US) increase in average gas price (Fig. 4). Incorporating pelt price and unemployment rate did little to improve model fit relative to our most-supported model (Table 1).

DISCUSSION

Our results show that different economic constraints influence participation in muskrat trapping and per capita muskrat harvest in Illinois. Number of individuals participating in muskrat trapping was related to all 3 economic variables we evaluated, but most strongly to current-year pelt prices. In contrast, per capita muskrat harvest was not related to pelt prices but related negatively to gas prices.

The positive effect of pelt price on participation in muskrat trapping was the dominant factor in our most-supported model. Higher pelt prices and, to a lesser extent, lower gas prices and higher unemployment rates, likely recruit fiscally oriented trappers into participation. Recruits may include individuals new to trapping or those who have trapped in the past (Siemer et al. 1994). Because trapper participation was so highly correlated with annual muskrat harvests during the years examined under our study, lower pelt prices in recent decades may be one explanation for declining muskrat harvest. However, other factors that could influence trapper participation over time, such as lack of recruitment of new trappers to compensate for attrition of older trappers, changing attitudes toward fur harvesting, or decreased access to wetland habitat for trapping, were not evaluated in our study.

Our top-ranked model of muskrat trapper participation also included the positive effect of the unemployment rate and negative effect of gas prices. Higher unemployment rates may lure individuals into fur harvesting to supplement their income or because of extra free time. Similarly, individuals may choose not to participate in muskrat trapping if travel between home and trapping areas is too costly. Miller and Vaske (2003) reported that hunting participation and effort in Illinois are affected by individuals' perceived lack of free time or restricted finances. It is plausible to assume trappers in Illinois are affected by similar personal constraints.

Per capita muskrat harvest was unaffected by pelt price, suggesting that any increased effort in these years did not result in increased per capita harvests. Less-experienced trappers recruited during years with higher pelt prices may not have been as effective at harvesting muskrats because they lacked the requisite skills necessary to be effective trappers. This relationship between experience, skills, and harvest success has been noted among hunters (Miller and Graefe 2000). Further, novice trappers may have been more limited by available habitat to exploit. Wetland habitat loss and degradation is pervasive (Zedler and Kercher 2005, Miller et al. 2009), especially in Illinois (Suloway and Hubbell 1994, McCauley and Jenkins 2005). Many remaining streams, wetlands, and agricultural drainage ditches suitable for muskrats occur on private property, and permission to trap on high-quality habitat may be secured by those trapping muskrats each year regardless of pelt prices, leaving little room for new participants. Miller and Vaske (2003) found

Table 1. Competitive models explaining variation in muskrat trapper participation and per capita muskrat harvest in Illinois, USA, from 1976 to 2011. Models ranked by descending ΔAIC_c values. K = number of parameters in the model; w_i = model weight; $-2l = -2$(log likelihood). Covariates included "pelt price" (market value for a muskrat pelt adjusted for inflation), "gas price" (average market value for a gallon of gasoline during a given year adjusted for inflation), and "unemployment rate" (average unemployment rate in Illinois during a given trapping season [Nov, Dec, and Jan]). We only present models $\Sigma w_i \geq 0.95$ along with the *Intercept only* model.

Model	K	ΔAIC_c	w_i	$-2l$
Muskrat trapper participation				
Pelt price + gas price + unemployment rate	5	0.00	0.91	46.35
Pelt price + unemployment rate	4	5.10	0.07	54.17
Intercept only	2	43.88	0.00	97.84
Per capita muskrat harvest				
Gas price	3	0.00	0.50	229.02
Gas price + pelt price	4	2.27	0.16	228.75
Gas price + unemployment rate	4	2.50	0.14	228.98
Intercept only	2	4.12	0.06	235.53
Unemployment rate	3	4.57	0.05	233.59
Gas price + pelt price + unemployment rate	5	4.95	0.04	228.72

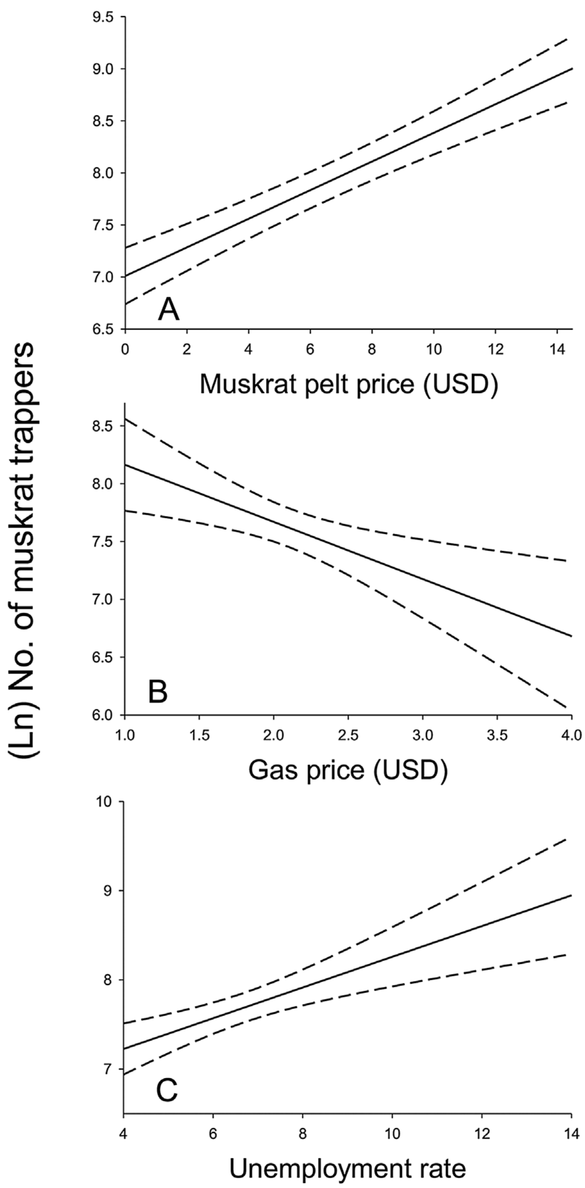

Figure 2. Relationships between covariates from our top model of muskrat trapper participation in Illinois, USA, from 1976 to 2011. Solid and dashed lines represent the predicted values (while holding other covariates at their median value) and 95% confidence limits, respectively. The number of muskrat trappers was influenced by (A) the average value for a muskrat pelt in U.S. dollars (USD), (B) average gasoline prices per gallon in U.S. dollars, and (C) the average unemployment rate in Illinois during the trapping season (Nov, Dec, and Jan).

access to land for hunting was the single greatest constraint to hunting participation among Illinois hunters. A similar constraint may also exist among trappers.

Our only supported model of per capita muskrat harvests suggests individual trapper harvest was influenced by gas prices. Muskrat trappers may have constricted their trapping area as travel costs increased, resulting in fewer muskrats harvested per individual. However, our model only captured 17% of the variation in per capita harvest, leaving 83% of the variation in annual per capita harvest unexplained. This unexplained variation may be due to factors affecting

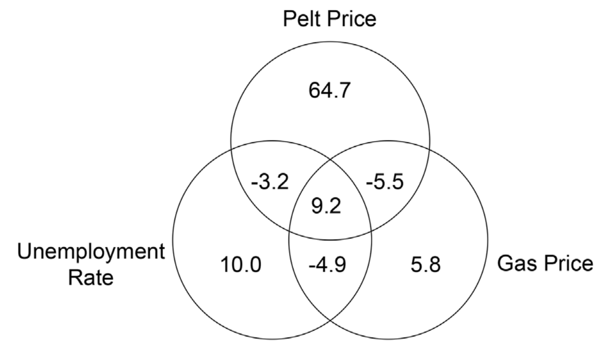

Figure 3. Partitioning of variation among the covariates in our most-supported model of muskrat trapper participation in Illinois, USA, from 1976 to 2011. Numerical values represent the percentages of variation explained by our most-supported model attributed solely to the effects of pelt prices, gas prices, and unemployment rates, and the varying combined effects of these covariates.

muskrat availability (e.g., changes in habitat availability, abundance, weather constraints, and trapping access) independent of economic influences. Future studies should investigate factors influencing per capita muskrat harvests and determine whether per capita harvests can inform wildlife or land managers about muskrat population dynamics.

To our knowledge, our study is the first to assess the relative economic biases present in muskrat trapper participation and harvest success and should be useful for wildlife biologists interested in exploiting historical muskrat harvest data sets. Roberts and Crimmins (2010) reported a diminishing correlation between pelt prices and muskrat harvest in eastern North America since 1946. They speculated that the reduced correlation between pelt price and muskrat harvest from 1986 to 2006 signified contemporary population declines in the region. However, they also freely admitted the evidence for this hypothesis was weak. To better understand current and historical muskrat population trends, it is imperative that biologists account for the strong effect of

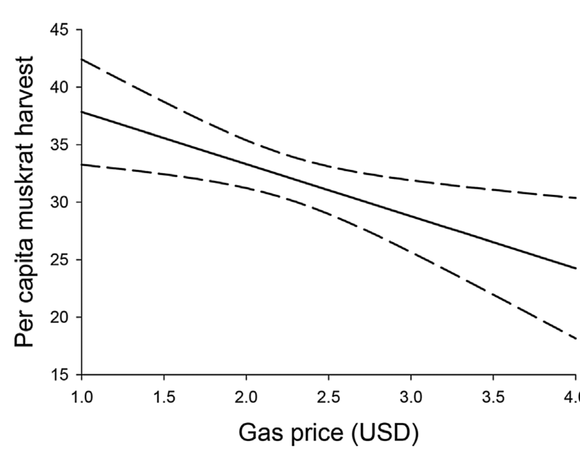

Figure 4. Relationship between gas price and per capita muskrat harvest in Illinois, USA, from 1976 to 2011. Solid and dashed lines represent predicted per capita harvest and 95% confidence limits, respectively, as estimated from our top model.

pelt prices in any analyses used to make population-level interpretations from harvest data.

MANAGEMENT IMPLICATIONS

Muskrat populations appear to be declining across North America, but the only geographically widespread, long-term information representing population trends exist in trapper harvest data. Applicability of these data requires information on relative factors associated with trapper participation and effort. Because participation in muskrat trapping is strongly influenced by pelt price, and to a lesser extent by gas prices and unemployment rates (all easily accessible data), managers can forecast interest in participation and plan for license sales accordingly. For instance, if muskrat pelt prices are above average during a given year, managers can expect increased interest in license purchases or larger enrollments in trapper-education courses. This information can be especially useful in areas with restricted trapping privileges (e.g., state and federal wildlife management areas) or in regions where there is concern about muskrat population persistence.

Muskrat harvest data can only be applicable to biologists interested in long-term trends in muskrat abundances after controlling for economic influences that affect these types of data sets. Without doing so, subsequent inferences will be biased and may flaw future analyses or population management plans. Although there are ways to statistically correct for these effects in fur harvest data sets, we recommend that state wildlife agencies begin collecting muskrat abundance data, independent of muskrat harvest data, using statistically robust methods (e.g., mark–recapture, distance sampling). Additionally, to improve regional comparisons, we recommend state agencies collaborate on using standardized data collection protocols.

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