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Research Article

Raccoon Pelt Price and Trapper Harvest Relationships Are Temporally Inconsistent

JAVAN M. BAUDER,[1] *Illinois Natural History Survey, Prairie Research Institute, University of Illinois, 1816 S. Oak Street, Champaign, IL 61820, USA*

KIRK W. STODOLA, *Illinois Natural History Survey, Prairie Research Institute, University of Illinois, 1816 S. Oak Street, Champaign, IL 61820, USA*

THOMAS J. BENSON, *Illinois Natural History Survey, Prairie Research Institute, University of Illinois, 1816 S. Oak Street, Champaign, IL 61820, USA*

CRAIG A. MILLER, *Illinois Natural History Survey, Prairie Research Institute, University of Illinois, 1816 S. Oak Street, Champaign, IL 61820, USA*

MAXIMILIAN L. ALLEN, *Illinois Natural History Survey, Prairie Research Institute, University of Illinois, 1816 S. Oak Street, Champaign, IL 61820, USA*

ABSTRACT Trapping data have a long and rich history of use in monitoring furbearer populations in North America but understanding the influences of variation in trapper harvest is important. Many factors besides abundance can cause variation in trapper harvest, including socioeconomics, weather, and motivation. The relationships between these extrinsic factors and trapper harvest may change temporally, which may obscure the causal understanding of variation in trapper harvest. We tested for changes in the relationships between pelt price and trapper numbers, and pelt price and harvest per trapper for raccoons (*Procyon lotor*) in Illinois, USA, from 1976–2018 while controlling for other socioeconomic (gasoline price, unemployment) and weather (temp, snow depth) factors. The annual raccoon harvest showed no clear trend, whereas the number of raccoon trappers declined markedly from approximately 1976–1990 in conjunction with pelt prices, after which the number of trappers remained relatively stable and were not significantly affected by pelt price. In contrast, harvest per trapper increased markedly during the 1990s and showed a significant negative relationship with pelt price pre-1990 but a positive relationship post-1990. We propose that declines in pelt prices resulted in a loss of less experienced or economically incentivized trappers, whereas contemporary trappers may continue trapping primarily for non-economic reasons. Our study highlights the potential for using non-linear relationships between trapper harvest data and socioeconomic covariates to help understand the influences of temporal variation in trapper harvest data.

KEY WORDS demography, furbearer, harvest, motivation, pelt prices, *Procyon lotor*, raccoon, trapping.

Annual harvest records have played an important role in understanding the ecology and population status of furbearing mammals (Fryxell et al. 1999, Erb et al. 2000, Viljugrein et al. 2001). Time series of furbearer harvest data, particularly trapping data, may span multiple decades (Peck et al. 1985) and often represent the only available data with which to evaluate species' trends over broad spatiotemporal extents (Roberts and Crimmins 2010, Newsome and Ripple 2015, Ahlers and Heske 2017). Accordingly, trapper harvest data are regularly used to estimate trends in furbearer populations for monitoring and management (White et al. 2015). Such data, however, are also a function of trapper numbers and individual trapper harvest, both of which may be affected by multiple factors independent of species abundance. Moreover, the relationships (i.e., slopes) between these factors and trapper harvest data may change temporally (Roberts and Crimmins 2010), which could further confound attempts to infer furbearer population trends from harvest data.

Pelt price is widely assumed to cause variation in trapper harvest data. Trappers are often motivated by economic rewards (Stabler et al. 1990, Siemer et al. 1994), and the number of trappers (Ahlers et al. 2016) or annual trapper harvest (Elsken-Lacy et al. 1999, Roberts and Crimmins 2010) are often positively related to pelt prices. In contrast, other researchers have reported little or no relationship between pelt prices and trapper harvest data (Webb and Boyce 2009, Landriault et al. 2012), particularly for species with restrictive seasons or harvests (Hiller et al. 2011, Kapfer and Potts 2012, Allen et al. 2019). Pelt prices for some furbearers have declined from peaks in the 1970s (Gehrt et al. 2002, Ahlers and Heske 2017), which may reduce the economic profitability of trapping, particularly for trappers with high operating costs, those unable to increase their harvest (e.g., unskilled trappers), or both. These price declines coincided with declines in trapper

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[1]*E-mail: javanvonherp@gmail.com*

numbers across North America (Siemer et al. 1994, Armstrong and Rossi 2000, McKelvey et al. 2011) although other factors have contributed also. For example, lack of recruitment has resulted in predominately older trappers (Armstrong and Rossi 2000, Boxall et al. 2001, Zwick et al. 2006), and loss of potential habitat (e.g., due to commercial agriculture or urbanization) or reduced access to private property may make it more difficult to trap (Miller and Vaske 2003). Furthermore, contemporary trappers may be increasingly motivated by non-economic factors (e.g., outdoor recreation, nature appreciation; Muth et al. 1996, Daigle et al. 1998, Dorendorf et al. 2016). Changes in trapper motivation, particularly the relative importance of economic and non-economic motives, combined with changing economic conditions may cause temporal changes in the relationships between pelt prices and trapper numbers, effort, and harvest. Yet most studies evaluating temporal variation in harvest data assume constant temporal relationships between harvest data and pelt price (Roberts and Crimmins 2010).

Factors other than pelt price may also cause variation in trapper harvest data. Gas prices may negatively affect trapper numbers and trapping effort by increasing the economic costs of trapping (Brinkman et al. 2014, Ahlers et al. 2016). Conversely, high unemployment rates may lead to increased trapper numbers and effort because of the potential income from trapping (Stabler et al. 1990, Ahlers et al. 2016) provided that pelt prices are high enough to provide sufficient financial incentives. Winter weather conditions may also contribute to the number of animals harvested. For example, trappers may be less likely to trap during colder winters (Stabler et al. 1990) when animals may behaviorally respond to increased snow depth or colder temperatures in a manner that reduces their susceptibility to harvest (Kapfer and Potts 2012, Landriault et al. 2012). Warmer winters may facilitate greater animal mobility and lead to increased trapping susceptibility (Suffice et al. 2020) but also reduce pelt quality potentially leading to lower trapper effort, harvest, or both. Finally, trapping season length and harvest limits may directly affect harvest and trapper effort in different ways. Increasing harvest limits or season length for restricted-harvest species may result in increased harvest (Hiller et al. 2011, Kapfer and Potts 2012), whereas restricting permit numbers may actually increase trapper participation for some species (Allen et al. 2018). The effects of these factors and their interactions with pelt price must also be considered to better understand sources of temporal variation in trapper harvest data for inferring population trends.

Raccoons (*Procyon lotor*) are a widespread and abundant furbearer (Lotze and Anderson 1979) that have been widely harvested by hunters and trappers (Peck et al. 1985, Clark et al. 1989, Stabler et al. 1990, Gehrt et al. 2002). In particular, raccoons are abundant throughout Illinois, USA (Heske et al. 1999, Lesmeister et al. 2015), and have been one of the most abundantly harvested furbearers in the state (Williams et al. 2018). Raccoons are capable of using diverse natural and anthropogenic landscapes including urban and agricultural areas (Pedlar et al. 1997, Gehrt 2003, Barding and Nelson 2008, Hadidian et al. 2010), and have been readily available to trappers currently and historically. Moreover, raccoons are often trapped as a management tool given their role as nest predators (DeGregorio et al. 2016) and disease vectors (Mitchell et al. 1999, Bateman and Fleming 2012). This makes understanding the factors influencing the number of trappers and their harvest important for wildlife managers who use trapping (and harvest data) as a management tool.

We evaluated the effects of pelt price, gasoline price, winter unemployment, winter temperature, and snow depth on the annual number of trappers (i.e., calculated as the number of trappers harvesting ≥1 raccoon in a given year) and annual harvest per trapper in Illinois over 43 years. In particular, we tested whether the relationships of pelt price with annual number of trappers and annual harvest per trapper differed between periods of high but declining pelt prices and low but stable pelt prices. We formulated the following hypotheses regarding the relationships between the dependent variables and our 5 covariates: 1) there is a positive relationship between annual number of trappers and annual harvest per trapper with pelt prices because more individuals may participate in trapping when prices are high, and those individuals may also increase their effort leading to greater individual harvests; 2) there is a negative relationship between annual number of trappers and annual harvest per trapper with gasoline price because individuals may be less likely to participate in trapping or trap less frequently or closer to home when gas prices are high; 3) there is a positive relationship between annual number of trappers and annual harvest per trapper with winter unemployment because individuals may be more likely to participate in trapping, trap more frequently, or both when unemployment is high; and 4) there is a negative relationship between annual number of trappers and annual harvest per trapper with winter temperature and snow depth because of restricted movement and activity of trappers, raccoons, or both. We predicted that pelt price would have a greater effect on number of trappers than on harvest per trapper and that pelt price would have a stronger influence than gasoline price and winter unemployment on number of trappers based on similar patterns reported by Ahlers et al. (2016) for muskrat (*Ondatra zibethicus*) trappers in Illinois. We predicted a stronger effect of gasoline price than pelt price on harvest per trapper based on Ahlers et al. (2016). We also predicted that winter temperature and snow depth would have comparatively weak effects on trapper numbers and harvest per trapper.

STUDY AREA

We collected state-wide trapper harvest data from Illinois during 1976–2018. Land cover varies widely across the state including highly urbanized areas in northeastern Illinois, agriculture in central Illinois, and hilly forests in southern Illinois. Topographic relief across the state is low to moderate and elevation ranges from 85–380 m above sea level. Row-crop agriculture is the dominant land cover, particularly in central and northern Illinois, and makes up approximately 75% of the state (~11 million ha; U.S. Department of Agriculture 2017). Land cover composition remained relatively stable during our study although urbanized land covers increased from approximately 4% to 8% (Walk et al. 2010). The climate is temperate continental with cold winters (monthly min. temp = −58.3–10.0°C) and warm summers (monthly max. temp = −46.1–25.6°C) and most precipitation falls April through October as rain (min. monthly precipitation = 0–1 cm, max. monthly precipitation = 0.2–24 cm, data from the National Oceanic and Aeronautics Administration [NOAA] using the RNOAA package [Chamberlain 2019] in Program R [R Core Team 2019]).

Illinois is divided into 2 trapping zones (northern and southern) split approximately into the northern and southern halves of the state. Trapping season length was equal between zones during all years except 1984, 1985, and 1990 (northern zone length = 47 days, southern zone length = 45 days). Mean trapping season length was 63 days and increased from 30 days in 1979 to 98 days in 2017 and 2018 (Fig. S1, available online in Supporting Information). The northern zone opened earlier than the southern zone ($\bar{x}$ opening dates of 9 Nov and 16 Nov, respectively, and $\bar{x}$ closing dates of 9 Jan and 16 Jan, respectively). There was no bag limit for raccoons during our study. Other harvested terrestrial mammalian fauna widespread throughout our study area included white-tailed deer (*Odocoileus virginanus*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), Virginia opossum (*Didelphis virginiana*), striped skunk (*Mephitis mephitis*), woodchuck (*Marmota monax*), squirrel (*Sciurus* spp.), and eastern cottontail (*Sylvilagus floridanus*).

METHODS

Harvest Data and Predictors

We collected trapper harvest data annually using repeat mail questionnaires (Appendix S1, available online in Supporting Information) following standard survey methods (Dillman et al. 2019). The University of Illinois Institutional Review Board (IRB) approved all research methods (IRB 10236). During 1976 the Illinois Department of Natural Resources (IDNR) and Illinois Natural History Survey provided questionnaires to all licensed trappers, and in subsequent years distributed questionnaires to a random sample of licensed trappers. The nature of questions within the questionnaire varied from year to year depending on the particular research and management needs of the survey administrators, but every year trappers were asked to report the number of nights trapped, number of traps set, number of each species harvested, and the county where they were harvested. We did not consider non-response bias because of our high response rates (see Results). The IDNR does not have mandatory harvest registration, and instead estimates annual trapper harvest, number of trappers, and harvest per trapper for furbearers from the responses to these questionnaires using the methods of Cochran (1953) and Snedecor and Cochran (1967).

We considered 5 independent variables that we hypothesized *a priori* would affect our dependent variables (Table 1): pelt price, gasoline price, unemployment during the trapping season, winter temperature, and winter snow depth. We acquired pelt prices ($\bar{x}$ annual raccoon pelt price in Illinois in U.S.$) from annual Fur Harvest Surveys (McTaggart 2018*a*) published by the IDNR. We converted all prices to 2018 prices using the mean annual seasonally adjusted Consumer Price Index (CPI; www.bls.gov/data/, accessed 4 Feb 2019). Pelt prices exhibited a steep decline from a high of $104.89 in 1978 until reaching $5.67 in 1990, after which prices remained low but relatively stable. We used mean annual retail gasoline prices (U.S.$/liter nominal prices, www.eia.gov/outlooks/steo/realprices/, accessed 4 Feb 2019) adjusted to 2018 prices as described above. We obtained the mean seasonally adjusted unemployment rate during the trapping season in Illinois (Nov–Jan; www.bls.gov/data/, accessed 4 Feb 2019). We obtained daily weather data across Illinois during 1976–2018 from NOAA using the RNOAA package. For each day during the trapping season, we calculated the maximum air temperature and snow depth for each station. We calculated the mean proportion of days during the raccoon trapping season (defined as 2 weeks prior to the earliest opening date through the latest closing date following Kapfer and Potts 2012) where daily maximum air temperature (°C) was ≤10°C (lower critical temperature for raccoons; Mugaas et al. 1984) and daily snow depth (cm) was ≥25 cm (estimated raccoon shoulder height).

Statistical Analyses

We used the number of trappers and harvest per trapper as our dependent variables and log-transformed them to meet our model assumptions of residual normality and homogeneity. We used Spearman's rank correlations to test for monotonic relationships between harvest metrics and year and conducted all analyses in Program R. We also tested for

Table 1. Descriptions and summary statistics for covariates used in the analysis of the annual number of raccoon trappers (i.e., number of trappers harvesting ≥1 raccoon in a given year) and harvest per trapper in Illinois, USA, 1976–2018. All currency values are reported in inflation-adjusted (2018) United States dollars ($). Temperature (°C) and snow depth (cm) values are the species-specific cutoffs used to calculate their respective covariates.

Name	Description	$\bar{x}$	SD	Range
Pelt price	$\bar{x}$ annual pelt price in Illinois adjusted to 2018 prices.	$22.92	$24.96	$3.60–$104.89
Gas price	$\bar{x}$ annual gasoline price ($/liter) adjusted to 2018 prices.	$9.92	$2.69	$6.01–$15.03
Unemployment	$\bar{x}$ percent seasonally adjusted unemployment in Illinois from Nov–Jan.	6.87	2.02	4.27–12.97
Temperature	$\bar{x}$ proportion of days during the trapping season in Illinois where maximum air temperature was ≤10°C.	0.65	0.09	0.48–0.82
Snow depth	$\bar{x}$ proportion of days during the trapping season in Illinois where snow depth was ≥25 cm.	0.14	0.10	0.00–0.41

linear correlations between the number of effective raccoon trappers and number of trapping licenses sold, between year and temperature, and between year and snow depth using Pearson's correlation tests. We tested for differences in temperature and snow depth between 1976–1990 and 1991–2018 using Wilcoxon sign-rank tests. We calculated the autocorrelation function for raccoon trapper harvest using the acf function in R (Venables and Ripley 2002) to test for cyclical patterns in harvest.

To test for time-varying effects of pelt price on our dependent variables, we created a binary covariate (i.e., pre-post-1990) denoting years during which pelt prices were high but declining (1976–1990) and years when pelt prices were low but stable (1991–2018). We modeled the relationship between our dependent variables and the log of pelt price by estimating the intercept, the slope during 1976–1990, and the change in slope between 1976–1990 and 1991–2018. This limited the number of parameters in our models and allowed us to derive the estimated slope during the second period as the sum of the slope during 1976–1990 and the change in slope between 1976–1990 and 1991–2018. We considered only models estimating up to 4 coefficients including the intercept ($K \leq 4$), because of our limited sample size ($n = 42$ yr). Collinearity among covariates in a given model was low [$r \leq 0.51$]).

Preliminary analysis of residual autocorrelation indicated that residuals were strongly correlated at a 1-year lag and that the autocorrelation was reduced when fitting models using every other year (i.e., half of the data). We therefore used a resampling approach analogous to bootstrapping to minimize residual autocorrelation by randomly subsampling half of the data (22 of 42 years) 10,000 times without replacement (De Bin et al. 2016). We fit each candidate model to each subsampled dataset. For each model, we calculated the proportion of subsampled datasets wherein the model was the top-ranked model (π) following Burnham and Anderson (2002) as an analog to Akaike's Information Criterion adjusted for small sample sizes (AIC_c) model weight. We also calculated the mean R^2 of each model.

To evaluate the effects of our independent variables, we calculated model-averaged parameter estimates across models containing a given covariate (Grueber et al. 2011) for each subsampled dataset. We report the median of each model-averaged parameter estimate and the 2.5th, and 97.5th quantiles as the 95% confidence intervals. We z-score standardized all continuous covariates (except logged pelt price) prior to subsampling our data to directly compare effect sizes. We derived a slope estimate for logged pelt price during 1991–2018 for each iteration and report its median and 95% confidence intervals.

We evaluated the predictive ability of our models during each subsampled dataset by comparing our hold-out values for that subsample with the model-averaged predicted values from each candidate model. We compared observed and predicted values using root-mean-squared error and Lin's (1989) concordance correlation coefficient, which ranges from 0–1 and quantifies the departure from a line with intercept = 0 and slope = 1.

Finally, we tested if harvest per trapper varied with trapping season length because trapping season length increased during our study. We re-ran the subsampling analysis using 10,000 iterations and 3 models: the interaction between pelt price and pre-post-1990, the interaction between pelt price and pre-post-1990 plus winter temperature, and the interaction between pelt price and pre-post-1990 plus season length. We averaged season length for the northern and southern zones for the 3 years when they differed, and z-score standardized season. We then evaluated the support for these 3 models and the significance of the model-averaged parameter estimate for season.

RESULTS

Trapper Harvest Questionnaires and Winter Weather

In 1976, the response rate was 17.5%, and from 1977–2018 the mean response rate to the questionnaire was 74.7 ± 7.2% (SD; range = 59.9–85.2%). During 1977–2018, the proportion of license holders increased ($r = 0.31$, $P = 0.044$), whereas the response rate declined ($r = -0.84$, $P < 0.001$). Trapping season length was strongly correlated with year ($r = 0.93$, $P < 0.001$). The mean proportion of days during the trapping season where daily maximum air temperature was ≤10°C and the daily snow depth was ≥25 cm showed very little change during our study (temperature: $r = -0.20$ $P = 0.202$; snow depth: $r = 0.26$, $P = 0.093$; Fig. S2, available online in Supporting Information). There was no significant difference in either of these climate variables between 1976–1990 and 1991–2018 (temp: $W = 249.00$, $P = 0.331$; snow depth: $W = 187.00$, $P = 0.571$).

From 1976–2018, trappers harvested 3,777,419 raccoons in Illinois. From 1979–2018 (the years during which zone-specific harvest data were collected), trappers harvested 2,131,704 raccoons in the northern zone and 1,345,148 raccoons in the southern zone. The correlation between year and total trapper harvest was weak ($r_s = -0.23$, $P = 0.132$; Fig. 1), indicating no clear trend over time. Median estimated annual statewide harvest was 120,134 (range = 35,825–141,588) from 1976–1990 and 78,218 (range = 41,125–151,367) from 1991–2018. Total annual trapper harvest (i.e., harvest) was correlated with number of trappers ($r_s = 0.73$, $P < 0.001$) and current-year pelt price ($r_s = 0.63$, $P < 0.001$) but not with harvest per trapper ($r_s = -0.07$, $P = 0.639$). We found no evidence of cyclical patterns in trapper harvest and the autocorrelation function was only significant at lag $k = 1$ (Fig. S3).

Number of Trappers

The number of trappers decreased temporally ($r_s = -0.51$, $P < 0.001$) with a median estimated annual statewide number of trappers of 9,570 (range = 1,945–15,340) from 1976–1990 and 2,525 (range = 1,176–4,799) from 1991–2018. The decline in number of trappers was strongest until approximately 1989, after which the number of trappers was relatively constant (Fig. 1). The number of raccoon trappers was strongly correlated with the number of trapping licenses sold ($r = 0.99$, $P < 0.001$).

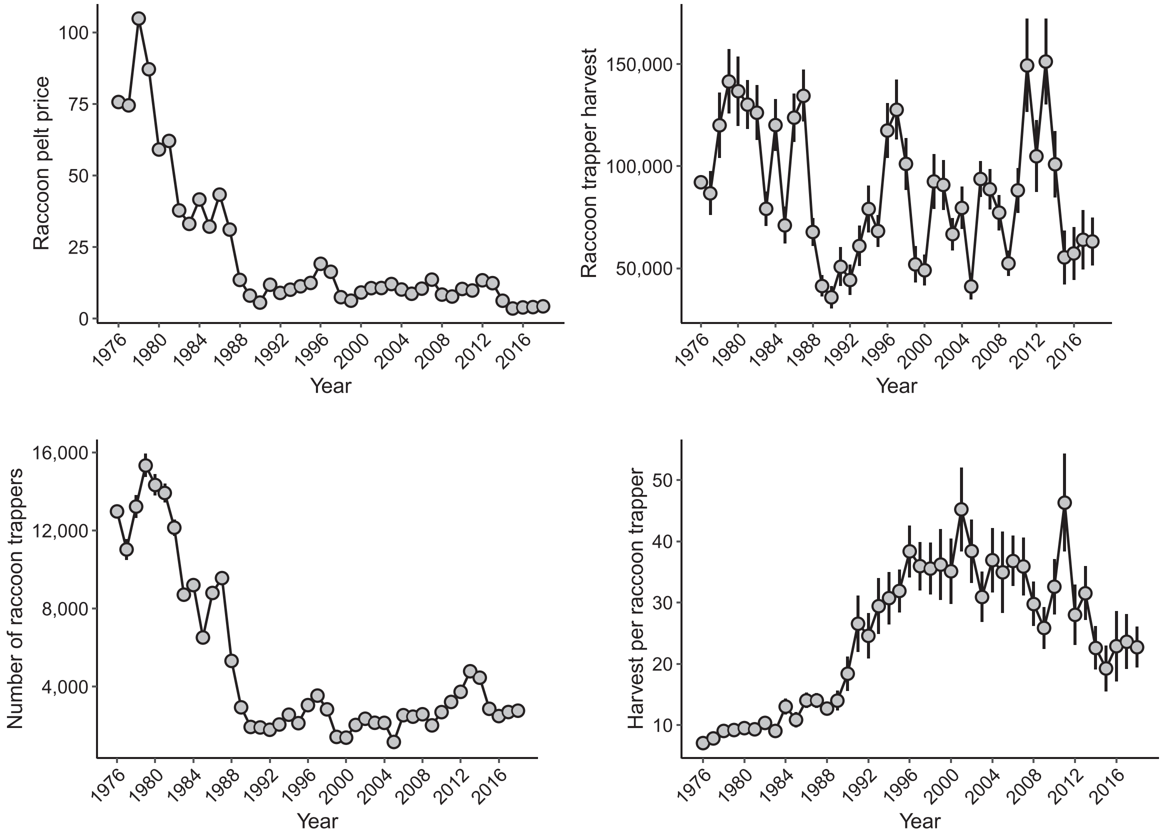

Figure 1. Estimates (and 95% CI) of annual raccoon trapper harvest, number of raccoon trappers, harvest per trapper, and mean annual pelt prices for raccoons in Illinois, USA, 1976–2018. We adjusted pelt prices to 2018 prices.

The top model for number of raccoon trappers included the interactive effect of pre-post-1990 and pelt price, and the additive effect of gasoline price ($\pi = 0.76$; Table 2). This model had approximately 4.6 times more support than the second-ranked model with only the interactive effect of pre-post-1990 and pelt price ($\pi = 0.16$). All models with the interactive effect of pre-post-1990 and pelt price had high mean R^2 values (0.82–0.86) and similar predictive abilities, although root-mean squared error clearly favored the top-ranked model (Table 2). There was a strong positive relationship between the number of trappers and pelt price during 1976–1990, but this relationship was weaker during 1991–2018 and the 95% confidence interval overlapped zero (Fig. 2). Gasoline price was the only covariate whose 95% confidence interval did not include zero (Fig. 2) and results indicated a positive relationship with the number of trappers (Figs. 2 and 3).

Table 2. Model rankings for number of raccoon trappers in Illinois, USA, 1976–2018. Models with pre-post-1990 × pelt price estimate separate slopes for pelt price during 1976–1990 and 1991–2018. We present the proportion of subsampled datasets where a model was the top-ranked model (π) using Akaike's Information Criterion adjusted for small sample sizes (AIC_c). We report the root-mean squared error (RMSE) and Lin's (1989) concordance correlation coefficient (CCC) between the predicted and observed values for the remaining data values.

Model	$\bar{x}$ ΔAIC_c	π	$\bar{x}$ R^2	$\bar{x}$ RMSE	$\bar{x}$ CCC
Pre-post-1990 × pelt price + gas price	0.37	0.756	0.86	685.15	0.97
Pre-post-1990 × pelt price	3.80	0.164	0.83	966.72	0.95
Pre-post-1990 × pelt price + snow depth	5.65	0.033	0.83	987.96	0.94
Pre-post-1990 × pelt price + unemployment	5.77	0.018	0.83	937.96	0.96
Pre-post-1990 × pelt price + temperature	6.43	0.010	0.82	975.30	0.95
Pelt price	12.40	0.000	0.74	1,714.84	0.91
Pelt price + unemployment + gas price	14.54	0.001	0.75	1,508.21	0.94
Pelt price + temperature + gas price	14.71	0.000	0.74	1,489.69	0.93
Pelt price + snow depth + gas price	14.79	0.000	0.74	1,486.86	0.93
Pelt price + snow depth + unemployment	16.04	0.000	0.73	1,670.05	0.92
Pelt price + temperature + unemployment	16.48	0.001	0.72	1,716.67	0.92
Pre-post-1990	16.85	0.018	0.65	2,462.27	0.75
Unemployment	38.16	0.000	0.17	5,129.13	0.19
Gas price	38.80	0.000	0.15	5,248.12	0.15
Temperature	40.33	0.000	0.09	5,616.66	0.08
Snow depth	41.92	0.000	0.03	5,934.88	0.00

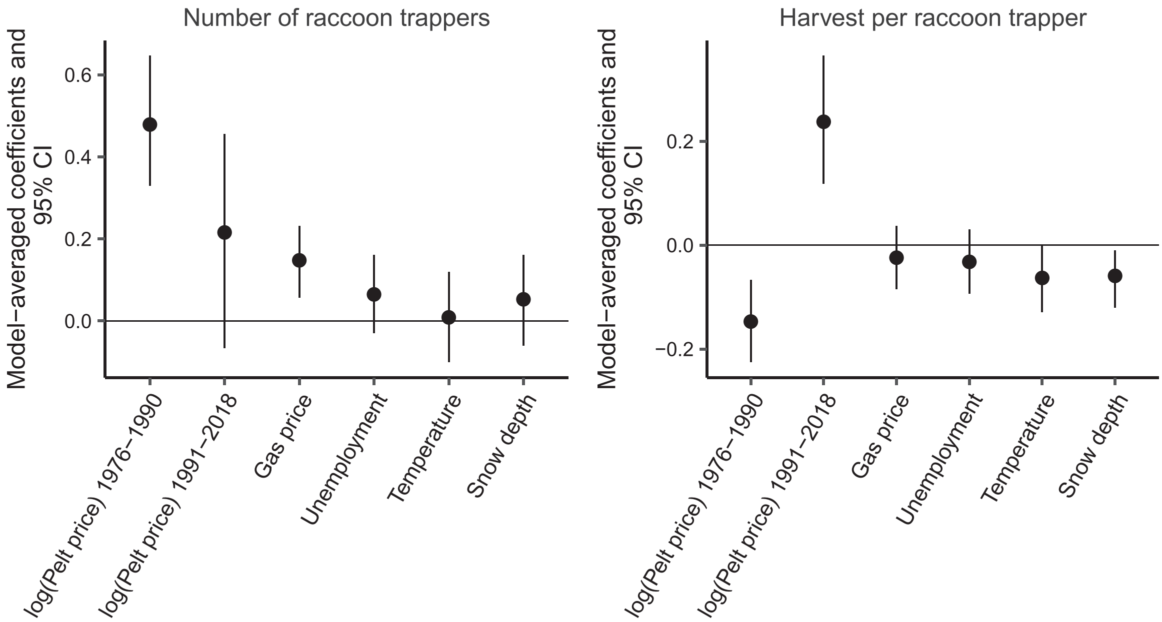

Figure 2. Model-averaged coefficient estimates for number of raccoon trappers and harvest per trapper in Illinois, USA, 1976–2018. Point estimates are the median model-averaged beta estimates from sampling 50% of the data 10,000 times and error bars are the 95% confidence intervals. All continuous covariates were *z*-score standardized prior to analysis.

Harvest Per Trapper

Harvest per trapper increased temporally ($r_s = 0.62$, $P < 0.001$; Fig. 1). The median estimated annual statewide harvest per trapper was 10 (range = 7–18) from 1976–1990 and 32 (range = 19–46) from 1991–2018.

There were 3 models explaining harvest per trapper with strong empirical support and all 3 models included the interactive effect of pre-post-1990 and pelt price (Table 3). The top model included the interactive term and temperature ($\pi = 0.35$). The second-ranked model included only the interactive term ($\pi = 0.28$) and the third-ranked model also included snow depth ($\pi = 0.24$). All models containing the interactive effect of pre-post-1990 and pelt price had high mean R^2 values (0.90–0.91) and similar predictive abilities (Table 3). Harvest per trapper had a strong negative relationship with pelt price from 1976–1990 but a strong positive relationship with pelt price from 1991–2018 (Figs. 2 and 3). Both temperature and snow depth were negatively related to harvest per trapper but only snow depth had 95% confidence interval that excluded zero (Figs. 2 and 3). Our *post hoc* analysis indicated that including trapping season length did not improve the empirical support for our models.

DISCUSSION

Pelt price influenced the number of raccoon trappers and the harvest per trapper in Illinois but these relationships changed temporally. Such non-linear relationships may have important implications for understanding influences of temporal variation in harvest data. For example, the strongest association between pelt price and the number of trappers was before 1990 when prices were high but declining. Economic rewards have historically been important motivators for trappers and financially motivated trappers may be less likely to participate in years when financial gains are expected to be low (Stabler et al. 1990, Siemer et al. 1994, Armstrong and Rossi 2000, Ahlers et al. 2016). Alternatively, declining pelt prices may simply render the operating costs of trapping too great to continue trapping, particularly for trappers with low marginal benefits (i.e., inexperienced trappers). In contrast, trappers participating during periods of low pelt prices may be primarily motivated by non-economic (recreational, communal, or personal achievement) reasons (Siemer et al. 1994, Daigle et al. 1998, Zwick et al. 2006, Dorendorf et al. 2016). The weaker relationship we observed between pelt prices and number of trappers post-1990, when pelt prices were low but relatively stable, may therefore reflect an underlying shift from a trapper population that was primarily motivated by economic reasons to one that is not. We did not directly measure trapper motivations (Daigle et al. 1998), however, and acknowledge that temporal changes in trapper motivations must be inferred indirectly from our data. Nevertheless, given the scarcity of longitudinal studies of trapper motivations (Zwick et al. 2006), tests for temporally changing relationships between trapper numbers and pelt price may be useful for identifying the presence and timing of motivational shifts in trapper populations.

A shift in trappers' primary motivation may at least partially explain the contrasting pattern we observed in harvest per trapper. The strong positive post-1990 relationship between pelt price and harvest per trapper was surprising, given the low number of raccoon trappers and relatively low value of pelt prices during this period. We offer 2 non-mutually exclusive hypotheses to explain this pattern. First, if post-1990 trappers continue to trap despite low pelt prices because of non-economic motivations (Siemer et al. 1994, Daigle et al. 1998, Zwick et al. 2006, Dorendorf et al. 2016),

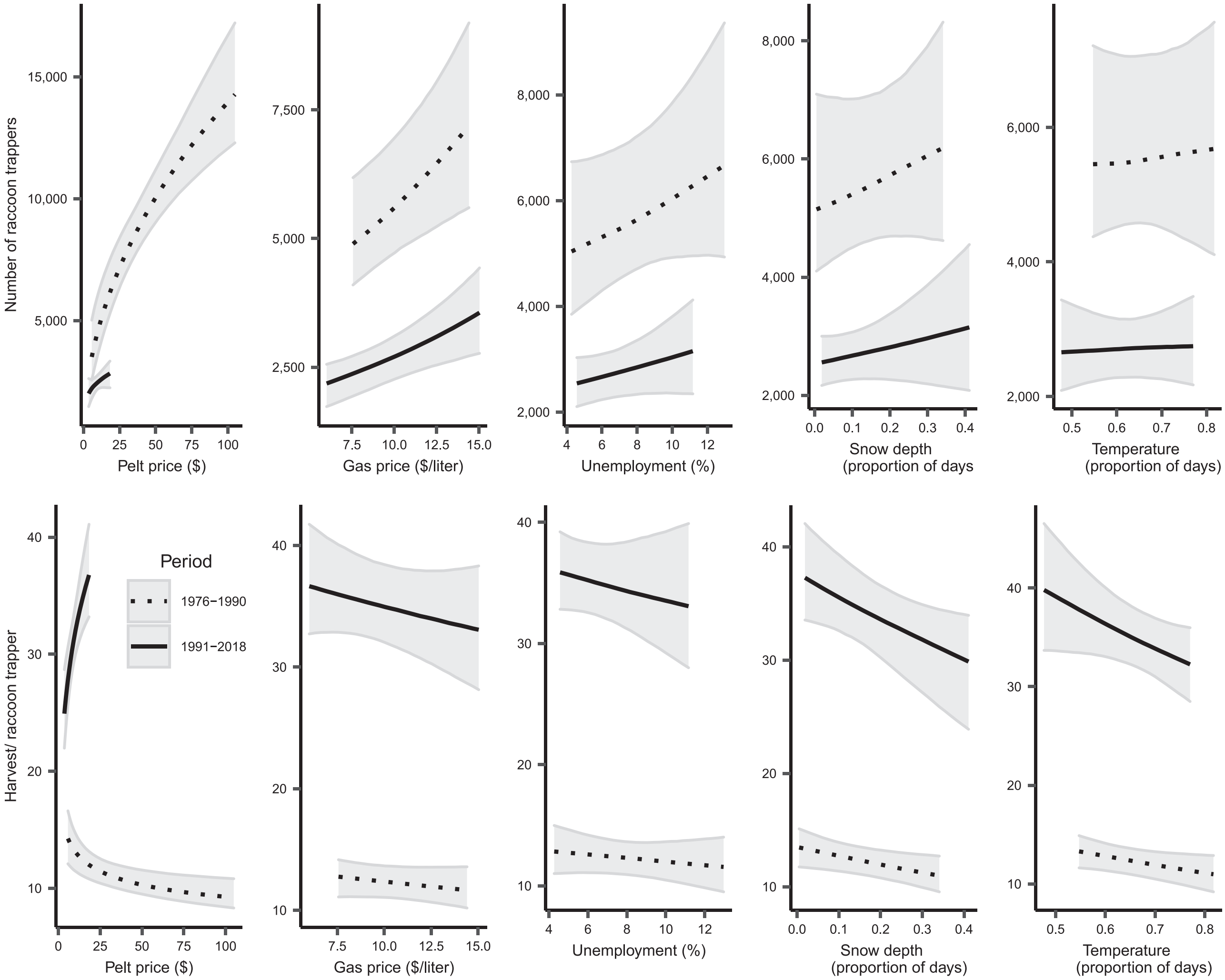

Figure 3. Model-averaged predicted values for number of raccoon trappers and harvest per trapper in Illinois, USA, 1976–2018. Point estimates are the median model-averaged predicted values from sampling 50% of the data 10,000 times and ribbons are the 95% confidence intervals of model-averaged predicted values. Predicted values span the range of observed values for each covariate within each time period.

Table 3. Model rankings for harvest per trapper for raccoons in Illinois, USA, 1976–2018. Models with pre-post-1990 × pelt price estimate separate slopes for pelt price during 1976–1990 and 1991–2018. We present the proportion of subsampled datasets where a model was the top-ranked model (π) using Akaike's Information Criterion adjusted for small sample sizes (AIC_c). We report the root-mean squared error (RMSE) and Lin's (1989) concordance correlation coefficient (CCC) between the predicted and observed values for the remaining data values.

Model	$\bar{x}$ ΔAIC_c	π	$\bar{x}$ R^2	$\bar{x}$ RMSE	$\bar{x}$ CCC
Pre-post-1990 × pelt price + temperature	1.89	0.349	0.91	2.71	0.92
Pre-post-1990 × pelt price	2.40	0.280	0.90	2.98	0.91
Pre-post-1990 × pelt price + snow depth	2.55	0.240	0.91	2.87	0.91
Pre-post-1990 × pelt price + gas price	4.14	0.088	0.90	2.98	0.91
Pre-post-1990 × pelt price + unemployment	4.72	0.042	0.90	2.93	0.91
Pre-post-1990	13.14	0.001	0.82	3.97	0.85
Pelt price	35.84	0.000	0.52	8.21	0.46
Pelt price + snow depth + unemployment	39.93	0.000	0.49	7.89	0.49
Pelt price + temperature + unemployment	40.30	0.000	0.48	7.90	0.49
Pelt price + snow depth + gas price	40.44	0.000	0.48	8.06	0.48
Pelt price + unemployment + gas price	40.66	0.000	0.47	8.01	0.47
Pelt price + temperature + gas price	40.78	0.000	0.47	8.10	0.47
Unemployment	49.15	0.000	0.13	12.80	0.20
Temperature	49.89	0.000	0.11	13.12	0.15
Gas price	51.01	0.000	0.06	13.89	0.06
Snow depth	51.73	0.000	0.03	14.36	0.01

they may also be more skilled or experienced, which may allow them to increase their individual harvest if pelt prices increase (Ruette et al. 2003). Furthermore, declines in trapper numbers due to declining pelt prices may have resulted in less competition for land access, allowing individual trappers greater opportunities for harvest, which may be particularly important in states like Illinois that are primarily private land (Miller and Vaske 2003). Although we were unable to estimate changes in the amount of raccoon habitat accessible to trappers during our study, both mean farm size (U.S. Department of Agriculture 2017) and the amount of urbanization (Walk et al. 2010) increased in Illinois, which could negatively affect trapper accessibility. Second, the increase in harvest per trapper may reflect increased raccoon abundance as indices for raccoon abundance in Illinois increased during the 1990s (Gehrt et al. 2002, McTaggart 2018*b*). Increased raccoon abundance may also lead to increased harvest even if trapping effort remains constant. Trappers may also be more likely to increase their effort if the perceived abundance of their target species is high (Dorendorf et al. 2016). We encourage additional research to more fully understand whether the observed increase in raccoon harvest per trapper in Illinois reflects changes in individual trapper effort (e.g., trap-nights), increased raccoon abundance, or both.

As we predicted, pelt price appeared to be the overriding factor affecting number of raccoon trappers. We also found evidence for other factors influencing both number of trappers and harvest per trapper. Surprisingly, gasoline price was positively related to the number of raccoon trappers, in sharp contrast to other studies (Brinkman et al. 2014, Ahlers et al. 2016). Gasoline prices were not strongly correlated with year ($r = 0.16$) or pelt price ($r = 0.23$) although they were moderately correlated with winter unemployment ($r = 0.51$). Inflation-adjusted gasoline prices did fall precipitously from 1980 until approximately 1998, which roughly corresponds to the sharp decline we observed in number of trappers. Gasoline price was more strongly correlated with the number of trappers during 1976–1990 ($r = 0.71$) compared to 1991–2018 ($r = 0.52$). The positive relationship between gasoline price and the number of raccoon trappers may partly be an artifact of pre-1990 declines in trapper numbers, possibly due to declining pelt prices and how the global economy has affected fur markets. Both snow depth and winter temperature appeared to negatively affect harvest per trapper, although model support for these covariates was relatively weak. We are unsure if these negative effects represent reduced susceptibility of raccoons to trapping, reduced trapper effort during more extreme winters, declines in raccoon abundance following extreme winters, or some combination of these factors. For example, Kapfer and Potts (2012) hypothesized that a negative relationship between winter temperature and bobcat (*Lynx rufus*) harvest in Minnesota was due to colder temperatures reducing bobcat activity and therefore their susceptibility to trapping. The relatively weak effects of gasoline price, unemployment, and weather on raccoon harvest data may reflect the high abundance and widespread distribution of raccoons in Illinois (Heske et al. 1999, Gehrt et al. 2002, Lesmeister et al. 2015).

Our results offer an interesting comparison with those of Ahlers et al. (2016) who conducted a similar analysis on number of muskrat trappers and harvest per muskrat trapper in Illinois during 1976–2011. Similar to our study, Ahlers et al. (2016) reported a strong positive relationship between number of trappers and pelt price. They also reported declines in muskrat trapper numbers similar to the declines observed over time in raccoon trapper numbers. In contrast to our results, they found a weak effect of pelt price on harvest per trapper despite a strong correlation between raccoon and muskrat pelt prices and number of successful trappers in Illinois ($r_s = 0.80$ and 0.85, respectively; Williams et al. 2018). Although this difference may be partially explained by our use of an interactive effect of year and pelt price, it may also reflect differences in population trends between muskrats and raccoons. Raccoons are a ubiquitous, terrestrial mesocarnivore in Illinois (Heske et al. 1999, Lesmeister et al. 2015). In contrast, muskrats are a semiaquatic herbivorous rodent that have likely undergone population declines across North America (Ahlers and Heske 2017). Annual muskrat trapper harvest in Illinois has sharply declined, whereas harvest per muskrat trapper has remained relatively stable (Ahlers et al. 2016) in contrast to patterns observed in both metrics for raccoons. Different life histories between raccoons and muskrats (terrestrial vs. semiaquatic, respectively) also necessitate the use of different trapping equipment and strategies between these 2 species, which may further contribute towards differences in harvest patterns. The contrasting patterns between raccoon and muskrat trapper harvest despite similar patterns in trapper numbers and pelt prices suggest differences in muskrat and raccoon population trends, muskrat and raccoon trapper behavior, or both. Additional data are required to test these 2 hypotheses.

MANAGEMENT IMPLICATIONS

Our findings of temporally inconsistent relationships between trapper harvest data and pelt price over 4 decades indicate changes in the manner in which pelt price could affect harvest. Consequently, accurate inferences of long-term population trends from harvested species should account for potentially confounding factors such as pelt price and species-specific trapper effort and temporal changes in trapper motivations. Doing so requires collecting long-term data on the demographic, sociological, and economic characteristics and motivations of trappers. We recommend that managers include questions to collect such data on trapper harvest questionnaires, at least on a periodic basis. Because our results suggest that contemporary trappers are motivated in large part by non-economic factors, managers seeking to retain and recruit trappers should highlight the non-economic aspects of trapping. Given the importance of mentoring when recruiting new trappers, managers should also encourage opportunities for trapper mentorship when promoting trapper participation.

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