HUMAN DIMENSIONS OF WILDLIFE
https://doi.org/10.1080/10871209.2019.1614241

Decreasing available bobcat tags appear to have increased success, interest, and participation among hunters

Maximilian L. Allen [a,b,c], Nathan M. Roberts[b], Morgan J. Farmer[c], and Timothy R. Van Deelen[c]

[a]Illinois Natural History Survey, University of Illinois, Champaign, Illinois, USA; [b]Wisconsin Department of Natural Resources, Rhinelander, Wisconsin, USA; [c]Department of Forest and Wildlife Ecology, University of Wisconsin, Madison, Wisconsin, USA

ABSTRACT

Management of wildlife populations has changed in the last century, coinciding with decreasing hunter populations and interest. Supply and demand suggest that reducing available harvest permits should increase the perceived value of permits, leading to an increase in hunter interest and motivation. We used annual harvest data and hunter surveys to study the effects of decreasing the supply of permits over two decades in Wisconsin. The number of permits issued was important in the top models for annual bobcat harvest and hunter participation. The decrease in the supply of permits was strongly correlated with increases in the number of applications for permits (R^2 = .82) and hunter participation (R^2 = .93), whereas increased hunter interest (applications and participation) was correlated with hunter success (percent of filled permits; $R^2_{applications}$ = .90, $R^2_{participation}$ = .93). This increasing trend in hunter populations and interest runs counter to general decreasing trends across North America and highlights the critical role of permit supply in wildlife management.

KEYWORDS

Bobcat; hunter participation; Lynx rufus; supply and demand; wildlife management

Introduction

Management of wildlife populations for harvest has undergone substantial changes in the last century (Anderson, 2002; Decker & Chase, 1997), with changes from market hunting and unregulated harvest to highly regulated harvest for sustained yield and recreation (Anderson, 2002; Festa-Bianchet, 2003). Managers use harvest regulations, including restricting the age of individuals (Balme, Hunter, & Braczkowski, 2012), season duration or geographical location (Mech, 2010), and sex of individuals that may be harvested (Clark & Tait, 1982), to influence harvest. The shift to highly regulated harvest for sustained yield and recreation has partially been driven by increasing urbanization and corresponding changes in lifestyle which, over the last century, have resulted in a greater diversity of stakeholder opinions on wildlife management (Decker & Chase, 1997; Manfredo, Teel, & Bright, 2003). This has resulted in increased interest in non-game species and a need for wildlife managers to provide recreational opportunities for a variety of non-hunting stakeholders (Anderson, 2002; Manfredo et al., 2003). Given that management agencies are charged with managing wildlife populations as

CONTACT Maximilian L. Allen maxallen@illinois.edu Illinois Natural History Survey, University of Illinois, 1618 South Oak Street, Champaign, Illinois, 61820

Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uhdw.

a public trust, they must reconcile the many differing opinions and values in their management strategies (Anderson, 2002; Rasker, Martin, & Johnson, 1992).

The broad cultural changes in how wildlife is viewed, including new public perceptions of wildlife harvest and characteristics of hunter populations, have altered harvest dynamics. Non-hunting wildlife stakeholders have increasing effects on harvest regulations through lobbying and the use of ballot initiatives (DeVos, Shroufe, & Supplee, 1998; Manfredo, Teel, Sullivan, & Dietsch, 2017). There are also growing concerns about a decrease in the number of hunters (Enck, Decker, & Brown, 2012; Heberlein, 1991; Ryan & Shaw, 2011) and a potential decrease in hunter interest due to a generally aging hunter population and increasingly restricted access to hunting land (Boxall, Watson, & McFarlane, 2001; Miller & Vaske, 2003; Stedman, Bhandari, Luloff, Diefenbach, & Finley, 2008; Winkler & Warnke, 2013). At the same time, there is often a perceived need by managers to set quotas to fill demand and increase hunter numbers or improve hunter satisfaction (Hammitt, McDonald, & Noe, 1989; Heberlein & Kuentzel, 2002), which is often tied to achievement and success of the hunt (Ebeling-Schuld & Darimont, 2017; Hammitt et al., 1989). There is also hesitancy to commercialize hunting despite the possibility that potential revenue from harvest permits could be an important aspect of maintaining revenue for agency funding (Winkler & Warnke, 2013). This changing demography of wildlife stakeholders, including aging hunter populations (Boxall et al., 2001; Winkler & Warnke, 2013), has contributed to changes in the factors driving annual harvests and hunter participation.

Hunter harvest and participation are important to harvest dynamics (Ahlers, Heske, & Miller, 2016; Hiller, Etter, Belant, & Tyre, 2011) but can be impacted by many factors, including economics, weather, wildlife populations, management restrictions, and hunter motivations. The harvest of many furbearers is motivated by the desire for recreation and the opportunity to benefit financially through selling pelts, and has traditionally made economic considerations, including pelt price and the cost of gasoline, important (Ahlers et al., 2016; Elsken-Lacy, Wilson, Heidt, & Peck, 1999; Kapfer & Potts, 2012). The weather in a given season can also affect hunter harvest and participation, as severe weather and snowfall can restrict animal movements and make people less willing to be outside, as well as affect wildlife populations (Kapfer & Potts, 2012). The number of animals in the target population can also clearly affect hunter success and therefore harvest (Leopold, 1986). However, past success or perceived opportunities for success may also make hunters more likely to participate in a given year. Wildlife managers can typically adjust three aspects when aiming to increase hunter satisfaction, harvest, and participation: (a) population density, (b) season length and restrictions, and (c) hunter numbers through the number of permits made available (Heberlein & Kuentzel, 2002). The supply of permits may also affect hunter demand for permits (e.g., Arrow, 1959) by increasing the perceived value of the permits, potentially increasing the effort and motivation among the reduced set of hunters who receive permits in a given year to ensure the success of harvesting an animal during their limited opportunity. An increase in the perceived value of the limited permits may also increase the number of hunters interested in obtaining a permit, thereby increasing the pool of potential hunters.

This study focuses on permits associated with bobcats. Bobcats are a widely distributed, solitary felid whose populations are spatially diffuse due to territoriality and low relative density (Allen, Wallace, & Wilmers, 2015; Bailey, 1974; Larivière & Walton, 1997).

Bobcats are commonly trapped or hunted with the aid of hounds across much of North America (Larivière & Walton, 1997), including in Wisconsin. Bobcats were likely distributed throughout Wisconsin before European colonization (Klepinger, Creed, & Ashbrenner, 1979), and a bounty system for bobcats was used in the state from 1867 through 1964 (Rolley, Kohn, & Olson, 2001). Mandatory registration of bobcat harvest began in 1973 (Rolley et al., 2001) and in 1980 managers implemented a bag limit of one per license coincident with a hunt that was restricted to the northern third of the state (Creed & Ashbrenner, 1975; Rolley et al., 2001). The current quota system that limits permits to one per season and is based on preference points (i.e., hunters who are unsuccessful in drawing a permit are awarded "preference points" that increase the probability of drawing a permit during subsequent drawings) was implemented in 1992 (Rolley et al., 2001) and a zone for the southern two-thirds of Wisconsin was added in 2014. Instances where the supply of hunting permits are restricted over the course of decades are rare, and the effects on hunter participation and success are currently unknown. Wisconsin's cumulative annual quotas of permits and harvested bobcats have been reduced over time compared to neighboring states and this appears to have shifted the harvest to a trophy hunt (Allen, Roberts, & Van Deelen, 2018; Kapfer & Potts, 2012). This makes Wisconsin an ideal population to study the effects of management restrictions on the supply of hunting permits and the resulting demand, interest, and success among hunters.

For this study, we were interested in determining factors driving the annual bobcat harvest data and hunter participation (derived from hunter surveys) in Wisconsin, U.S.A. across two decades. We used a suite of variables (Table 1) that are known to affect hunter harvest and participation, including economic factors, winter severity and snowfall, wildlife population and harvest success indices, and management restrictions (number of tags issued). We compared candidate models using generalized linear models (GLM) in an Akaike Information Criterion (AIC) framework for the factors driving annual harvest and hunter participation. We also used linear regression comparisons to understand how hunter harvest and participation have changed with the number of permits issued (the primary mechanism of harvest management in the state) and applications for permits. We predicted an inverse correlation between number of permits issued and number of applications because a decreasing number of permits issued could led to a perceived increase in the value of a permit, leading to an increasing number of hunters applying for permits. We predicted an inverse correlation between the number of permits issued and success because a decreasing number of permits issued could make it easier to successfully fill a permit due to decreased competition for an increasing population. We predicted a positive correlation between the number of applications and success because an increasing success rate could increase interest in obtaining a permit and increase the number of applications. We predicted an inverse correlation between the number of permits issued and hunter participation because a decreasing number of permits issued could lead to an increase in participation among hunters who received permits due to the scarcity of the opportunity to participate. We predicted a positive correlation between the number of applications and hunter participation because an increasing number of applications could lead to an increase in participation among hunters who received permits due to competition for the opportunity to participate.

Table 1. The variables used to model annual variation in Wisconsin's bobcat harvest and hunter participation (1993–2014).

Name	Abbreviation	Description	Reason
Available Permits	PERMITS	The number of permits issued annually	The number of permits issued should directly affect the number of animals harvested (Leopold, 1986), and fewer permits being available could positively affect hunter participation (Arrow, 1959)
Applications for Permits	APPLICATIONS	The number of hunters who applied for bobcat permits	Increased applications will indicate increased interest and correlate with increased hunter participation (Allen et al., 2018)
Pelt Price	PELT	The mean annual price in dollars for a bobcat pelt	Years with increased pelt prices will see increases in harvest and hunter participation (Elsken-Lacy et al., 1999, Kapfer & Potts, 2012)
Gasoline Price	GAS	The mean annual price in dollars for a gallon of gasoline	Higher gasoline prices will negatively affect hunter participation (Ahlers et al., 2016)
Winter Severity	WINTER	The WDNR index of winter severity based on temperature and snow depth	Winters with greater severity will reduce bobcat activity and increase the difficulty of hunting, making hunters less likely to participate (Kapfer & Potts, 2012)
Snowfall	SNOW	Snow depth in inches for the month of December	Winters with greater snow depth will restrict bobcat movements and make hunters less likely to participate (Kapfer & Potts, 2012)
Bobcat Harvest Trend	HARVEST	The mean number of bobcats harvested in the previous three years	The trend in harvest will indicate the short-term trend in harvest and hunter participation
Kittens Harvested	KITTENS	Percent of kittens in the harvest from previous year	Years following a high harvest of kittens will have negative effects on populations, leading to lower harvests (Leopold, 1986)
Bobcat Population	POPULATION	The WDNR estimate of the bobcat population	Higher bobcat populations will increase both bobcat harvests and hunter participation (Heberlein & Kuentzel, 2002)
Hunter Participation	PARTICIPATION	The percent of hunters with permits that participate in the season	The number of bobcats harvested will increase when more hunters participate (Heberlein & Kuentzel, 2002)
Total Incidental Catch	BYCATCH	The number of bobcats caught and harvested incidentally as bycatch while trapping other animals	The number of bobcats caught incidentally as bycatch will be an index of population size and years with greater incidental catches correlated with increased populations. Increased populations will increase harvest (Heberlein & Kuentzel, 2002)

Methods

We used data from bobcats harvested in Wisconsin from 1993 to 2014. Due to limited sample sizes from the southern zone, which opened for legal harvest in 2014, we only examined bobcat harvests in the northern zone (zone delineated by Highway 64). Since 1973, the Wisconsin Department of Natural Resources (WDNR) has required bobcat hunters to register any harvested bobcat within five days after the month of harvest, including submission of the skinned bobcat carcass. The WDNR has tracked harvest information including the annual harvest, hunting permits issued, the number of applications for hunting permits, the number of bobcats incidentally caught, and the proportion of kittens in the harvest. Our methods were carried out in accordance with approved guidelines from the WDNR and the University of Wisconsin, as an analysis of harvest data did not include any experimental protocols or handling of animals. All data are archived by the WDNR and fully available to the public.

We considered many factors that can affect hunter harvest and participation, including the broad categories of wildlife populations, management restrictions, weather, and economics. Each of the variables and reason behind it is in Table 1. How we collected the data for each variable is as follows. We used the annual bobcat population estimate from the WDNR (Roberts & Dennison, 2017) as our values for the bobcat population. We used annual bobcat hunter surveys created by the WDNR to calculate annual hunter participation. For these, the WDNR sent surveys after the hunting season to every hunter who received a bobcat permit from 1993 to 2014. Each annual survey was sent to every bobcat hunter who received a permit, and a follow-up was sent to all non-respondents. Annual response rates averaged 72% (range 62–77%, Table 2). Hunters were asked specific questions about their methods used during the season with the questions being similar across years, although additional questions were included over time.

We evaluated Wisconsin's winter severity index (WSI; Kohn, 1978) and monthly snowfall in season as a predictor of change in bobcat harvests. The WSI is a measurement of days when furbearers, including bobcats, will be inactive or restricted in their movements. This index sums the number of days with a minimum temperature of $\leq -17.8^{oc}$ as a measure of cumulative over-winter air-chill, and the number of days with $\geq$20.3 cm of snow on the ground to estimate the snow hazard. Days, when both conditions occurred, are scored as 2. These are summed from 1 December through 30 April to obtain the WSI. To measure winter severity, daily snow depths and minimum temperature were collected at 34 WDNR stations across our study area from 1 December through 30 April. For monthly snowfall, we considered snowfall totals from the month of December from three weather stations in our study area, which we obtained from the Wisconsin State Climatological Center (http://www.aos.wisc.edu/~sco/clim-history/data-portal.html).

We collected the price paid to bobcat hunters for pelts and used the yearly mean as the annual value of pelts. We then adjusted the price of pelts for inflation by calculating the value in 1993 for each year using an inflation calculator (www.usinflationcalculator.com). For gasoline, we used the mean annual price of a gallon of gasoline for Wisconsin, which we obtained through the United States Department of energy (http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=WI). We then adjusted the price of gasoline for inflation by calculating the value in 1993 for each year using an inflation calculator (www.usinflationcalculator.com).

Table 2. Summary of annual permits issued, bobcats harvested, and the data from bobcat hunter/trapper surveys. Data include the number of surveys sent, responses received, response rate, the percent of hunters/trappers who actively participated, the percent of hunters/trappers who harvested a bobcat, and the success rate for each method.

Year	Permits issued	Total harvest	# of surveys sent	# of responses	Response rate (%)	% that hunted bobcats	% that harvested a bobcat	Hound hunter success rate (%)	Other hunter success rate (%)	Trapper success rate (%)
1993	2,000	160	2014	1393	69.2	54.5	16.4	16.4	1.4	22.5
1994	2,000	169	2000	1465	73.3	55.2	17.6	29.8	4.2	16.5
1995	2,000	111	2000	1445	72.3	54.6	12.2	23.4	4.1	10.9
1996	2,000	166	2000	1446	72.3	53.1	18.7	33.3	4.9	18.3
1997	2,000	216	2000	1486	74.3	65.5	18.1	20.0	4.0	25.0
1998	1,860	194	1860	1432	77.0	57.1	17.9	24.0	6.0	20.0
1999	1,540	187	1540	1154	74.9	60.0	22.8	32.0	13.0	19.0
2000	1,490	279	1490	1055	70.8	62.9	30.4	45.0	9.0	23.0
2001	780	152	781	482	61.7	65.8	29.3	36.3	13.7	28.0
2002	1,330	250	1330	993	74.7	68.3	25.8	23.5	6.0	33.9
2003	1,380	371	1379	956	69.3	76.3	34.9	47.2	12.5	28.9
2004	1,370	362	1352	942	69.7	78.3	34.9	41.7	19.4	33.7
2005	1,540	497	1541	1075	69.8	72.9	44.9	58.5	18.1	38.4
2006	1,000	356	1000	712	71.2	73.6	41.0	43.2	24.4	45.8
2007	1,030	477	1030	698	67.8	80.2	57.7	70.9	29.1	46.4
2008	540	367	540	394	73.0	84.7	70.6	79.2	47.6	60.6
2009	475	271	477	342	71.7	83.2	59.8	79.2	47.6	60.6
2010	455	349	455	333	73.2	82.3	72.9	83.4	25.0	38.0
2011	475	357	475	327	68.8	87.1	64.3	72.3	n/a	59.6
2012	165	242	165	113	68.5	88.5	72.0	74.7	n/a	59.3
2013	215	226	215	158	73.5	85.4	68.7	82.1	n/a	44.4
2014	310	264	386	291	75.4	88.8	65.2	76.8	n/a	61.4

Statistical Analyses

We used program R version 3.3.1[36] for all our statistical analyses, and we considered $p \leq .05$ to be statistically significant. In each analysis, we used data from 1993–2014 to coincide with the duration of our shortest dataset (the bobcat hunter surveys). We first fit our data to distributions and tested for normality. When necessary, we log-transformed the data to fit a Gaussian distribution to meet the assumptions of our statistical analyses. In our AIC model comparisons, we first tested for correlation in the independent variables for our models and adjusted or removed any models with strongly correlated variables. We then plotted the residuals of each model using Tukey-Anscombe plots to examine for variance in the residuals. We then tested for temporal correlation in each model using the autocorrelation function in the *nlme* package (Pinheiro et al., 2018).

To determine what drives the annual number of harvested bobcats, we used a suite of variables (Table 1) to create 18 candidate models. We used GLMs for Gaussian data with a log link for each model where we used the annual harvest as our dependent variable and the variables in the candidate model as our independent variables. We compared the models using their AICc weights where we considered all of the models needed to reach a cumulative AICc weight of 0.90 to be our top models (Burnham & Anderson, 2003).

We used a series of linear regressions to test if the number of permits issued, and the number of applications were correlated with each other or hunter success (percent of filled permits) and hunter participation. In our regression analyses, we considered multiple R (R^2) ≥ .70 to be a strong correlation and $R^2 \leq .30$ to be a weak correlation.

To determine what drives the participation of bobcat hunters, we used a suite of variables (Table 1) to create 18 candidate models. We used variables from 1993–2014, which coincided with our bobcat hunter surveys. We used GLMs for Gaussian data with a log link for each of the models with the percent of hunters who participated as our dependent variable and the variables in the candidate model as our independent variables. We compared the models using their AICc weights where we considered all of the models needed to reach a cumulative AICc weight of 0.90 to be our top models (Burnham & Anderson, 2003).

Results

Annual Harvest

Annual numbers of bobcats harvested in the northern zone of Wisconsin since mandatory registration began in 1973 have varied by year and decade (Table 2). Our top models for the annual bobcat harvest from 1993–2014 were Bobcat Population ($_{w}$AIC = 0.60, intercept = 4.1801, ß$_{\text{POPULATION}}$ = 0.0004), Bobcat Population x Hunter Participation ($_{w}$AIC = 0.24, intercept = 3.8728, ß$_{\text{POPULATION}}$ = −0.0009, ß$_{\text{PERMITS}}$ = −4.2327, ß$_{\text{POPN x PERMITS}}$ = 0.0017), and Bobcat Population + Kittens Harvested + Total Incidental Catch ($_{w}$AIC = 0.09, intercept = 3.8728, ß$_{\text{POPULATION}}$ = 0.0005, ß$_{\text{KITTENS}}$ = 0.007, ß$_{\text{BYCATCH}}$ = −0.0117; Table 3).

Table 3. Results of AIC model comparisons for annual harvest of bobcats in Wisconsin (1993–2014). Our top models (those within a cumulative wAICc of ≤0.90) are in regular font and non-informative models are in italics.

Model	AICc	ΔAICc	wAICc	Cumulative wAICc
POPULATION	247.94	0.00	0.60	0.60
POPULATION * PARTICIPATION	249.77	1.84	0.24	0.84
POPULATION + BYCATCH + KITTENS	251.82	3.88	0.09	0.92
*HARVEST + PERMITS * PELT*	*253.72*	*5.78*	*0.03*	*0.96*
*POPULATION * PERMITS*	*254.07*	*6.13*	*0.03*	*0.99*
PERMITS + HARVEST	*255.77*	*7.83*	*0.01*	*1.00*
*PARTICIPATION * PELT*	*259.00*	*11.07*	*0.00*	*1.00*
*POPULATION * PERMITS * PELT*	*260.13*	*12.20*	*0.00*	*1.00*
HARVEST	*263.60*	*15.67*	*0.00*	*1.00*
BYCATCH	*265.43*	*17.49*	*0.00*	*1.00*
PARTICIPATION	*267.42*	*19.49*	*0.00*	*1.00*
*HARVEST * KITTENS*	*268.45*	*20.52*	*0.00*	*1.00*
PELT	*268.54*	*20.61*	*0.00*	*1.00*
PERMITS	*268.94*	*21.00*	*0.00*	*1.00*

Bobcat Applications and Permits Issued

The number of permits issued in Wisconsin has decreased over time with 2,000 permits issued annually from 1993 to 1997 to fewer than 500 permits annually from 2009 to 2014. During this same time, the number of applications for bobcat permits increased and demonstrated a significant and strong negative correlation with the permits issued ($F_{1,\ 20}$ = 40.57, R^2 = .82, $p < .0001$; Figure 1).

The percent of filled permits has increased from 1993 to 2014 with fewer than 10% of permits filled from 1993 to 1996 and more than 50% of permits filled from 2010 to 2014. The number of permits issued and success (the percent of filled permits) has had a significant and strong inverse correlation over time ($F_{1,\ 20}$ = 128.92, R^2 = .93, $p < .0001$; Figure 1). The number of applications and the percent of filled permits had a significant and strong correlation over time ($F_{1,\ 20}$ = 86.10, R^2 = .90, $p < .0001$; Figure 1).

Hunter Participation

Hunter participation, calculated as the percent of hunters with permits who actively hunted during the season, increased over time from approximately 50% of hunters with

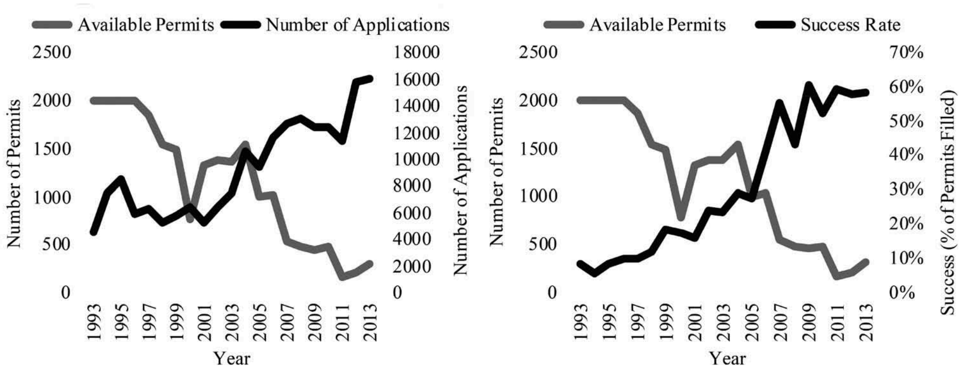

Figure 1. The inverse correlation of the number of permits issued (gray lines) with the number of applications (black line in left figure) and the percent of filled permits (black line in right figure).

permits during 1993 to 1996 to more than 85% during 2011 to 2014 (Table 2). The number of permits issued and hunter participation had a significant and strong inverse correlation over time ($F_{1,\ 20}$ = 87.92, R^2 = .93, p < .0001; Figure 2). The number of applications and hunter participation had a significant and strong correlation over time ($F_{1,\ 20}$ = 42.55, R^2 = .89, p < .0001; Figure 2).

When considering the factors best explaining hunter participation, our top models were Available Permits x Pelt Price ($_w$AIC = 0.60; intercept = −0.00935, $ß_{PERMITS}$ = −0.00046, $ß_{PELT}$ = −0.00133, $ß_{PERMITS\ x\ PELT}$ = −0.00001), Bobcat Population x Available Permits ($_w$AIC = 0.16; intercept = 0.0093, $ß_{POPULATION}$ = 0.0003, $ß_{PERMITS}$ = 0.0004, $ß_{PERMITS\ x\ POPULATION}$ = 0.0001), and Available Permits + Bobcat Harvest Trend ($_w$AIC = 0.14; intercept = −0.2583, $ß_{PERMITS}$ = −0.0002, $ß_{HARVEST}$ = 0.0005; Table 4).

Discussion

Our top models for annual bobcat harvest and hunter participation highlight the importance that the increasingly restricted number of permits have to the harvest dynamics of

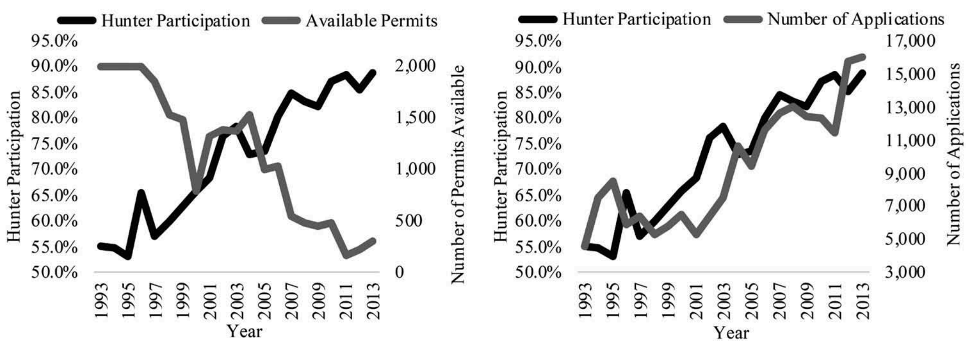

Figure 2. Annual hunter participation (black lines) and the inverse correlation with the number of permits available (gray line in left figure) and the correlation with the number of applications (gray line in right figure).

Table 4. Results of AIC model comparisons for the participation of bobcat hunters in Wisconsin (1993–2014). Our top models (those within a cumulative wAICc of ≤0.90) are in regular font and non-informative models are in italics.

Model	AICc	ΔAICc	wAICc	Cumulative wAICc
PERMITS * PELT	−63.55	0.00	0.60	0.60
PERMITS * POPULATION	−60.93	2.62	0.16	0.76
PERMITS + HARVEST	−60.65	2.90	0.14	0.90
PERMITS	*−58.98*	*4.57*	*0.06*	*0.96*
*POPULATION * PELT*	*−56.99*	*6.56*	*0.02*	*0.99*
POPULATION	*−55.40*	*8.15*	*0.01*	*1.00*
*PELT * GAS*	*−51.85*	*11.70*	*0.00*	*1.00*
*POPULATION * PERMITS * PELT*	*−50.69*	*12.86*	*0.00*	*1.00*
*APPLICATIONS * HARVEST*	*−50.61*	*12.94*	*0.00*	*1.00*
APPLICATIONS	*−47.40*	*16.15*	*0.00*	*1.00*
*APPLICATIONS * PELT*	*−46.77*	*16.78*	*0.00*	*1.00*
*PERMITS * WINTER * SNOW*	*−42.31*	*21.25*	*0.00*	*1.00*
*APPLICATIONS * WINTER * SNOW*	*−36.16*	*27.40*	*0.00*	*1.00*
PELT	*−27.73*	*35.83*	*0.00*	*1.00*
*WINTER * SNOW*	*−20.82*	*42.73*	*0.00*	*1.00*

bobcats in Wisconsin. Participation has increased over the last two decades, and our top model for hunter participation was 'Available Permits x Pelt Price' followed by 'Bobcat Population x Available Permits' and 'Available Permits + Bobcat Harvest Trend.' Our top models for annual harvest were 'Bobcat Population,' 'Bobcat Population x Hunter Participation,' and 'Bobcat Population + Kittens Harvested + Total Incidental Catch.' The common variables among top models for harvest and hunter participation were the bobcat population and the number of permits issued. Bobcat hunting in Wisconsin is relatively unique (e.g., Kapfer & Potts, 2012) with the increasingly restricted permits but high success rates (Allen et al., 2018), leading to our natural experiment. We relied on correlations among variables to discern patterns, which limit our ability to discern direct causation or potentially nuanced changes, but our findings highlight the importance of future research on the role of supply and demand in wildlife management.

The restricted bobcat permits and increasing success have occurred over time, and correlate with substantially increasing hunter populations and hunter interest. A decrease in the availability of permits was also correlated with increases in the number of applications for permits and hunter participation, whereas the increased interest (applications and participation) was also correlated with success (percent of filled permits). These increasing trends may run counter to trends of decreasing or stable hunter populations across much of North America (Enck et al., 2012; Heberlein, 1991; Ryan & Shaw, 2011). Since instituting the quota system in 1992, participation by bobcat hunters (the number of hunters with permits who actively participate) has increased from approximately 50% in the 1990s to more than 80% in the last few years. The actual mechanisms for this cultural shift may be complex. For example, decreasing the availability and increasing demand accompanied by increasing success and trophy hunts (e.g., Allen et al., 2018; Kapfer & Potts, 2012) may be causing a positive feedback loop, creating even greater interest and demand for the limited permits available. Hunter participation can be an important influence on the number of animals harvested (Ahlers et al., 2016; Hiller et al., 2011) and may be a factor in the increase in the percent of permits filled annually. Our top three models for hunter participation included the variable measuring number of permits available, which highlights the critical role that permit availability plays in managing furbearers through hunter participation. Pelt price was also in our top model, making it an important aspect of hunter participation (e.g., Ahlers et al., 2016), although it was not important for annual harvest as has been found in other areas (e.g., Elsken-Lacy et al., 1999; Gehrt, Hubert, & Ellis, 2002). Weather is anecdotally thought to affect hunter participation and furbearer harvests but also was not important in our models. However, future studies could explore this at finer spatiotemporal scales.

There may also be other contributing factors that we did not measure, such as promoting bobcat hunting or anecdotal sharing of success among potential bobcat hunters that increase interest. Although hunter populations are generally growing older (Boxall et al., 2001; Miller & Vaske, 2003; Winkler & Warnke, 2013), the human population in Wisconsin has also been growing over this time and increasing hunter numbers could be partly due to these population increases. Additionally, management variables, including quota size and season length, could also affect hunter participation (e.g., Hiller et al., 2011). These variables were steady over the course of our study, but the bobcat season was split into two shorter seasons in 2015 and could have effects on bobcat harvest and hunter participation in the future. These changes in hunter participation are also likely to coincide with changes in hunter demographics, such as the increasing trend in the number of hound hunters compared to trappers in Wisconsin.

The common variable in all three of our top models for annual harvest was 'Bobcat Population,' indicating the importance of bobcat management within Wisconsin. In the last five decades, bobcat management in Wisconsin has undergone substantial change, first transitioning from a bounty system to a bag limit of one with mandatory registration (Allen et al., 2018; Rolley et al., 2001). Originally, the decrease in the number of bobcat permits issued was driven by concern about the potential to overharvest the bobcat population. In 1990, litigation initiated to halt bobcat harvest, based on the perceived potential vulnerability of the species to overharvest, was unsuccessful (Rolley et al., 2001). However, the state did implement a reduced, conservative quota system based on harvest trends, bobcat population estimates, and stakeholder perception in response to the concerns over the potential vulnerability of the bobcat population (Rolley et al., 2001). Bobcat populations have since increased and expanded to the south and were part of our top annual harvest models and our second-best model for hunter participation. The increasing population is likely partly responsible for the increase in hunter success and reducing the number of permits and therefore restricting the number of animals harvested annually may have increased the population over time by reducing overall harvest mortality.

Annual furbearer harvests have historically correlated with pelt price (Elsken-Lacy et al., 1999; Gehrt et al., 2002) and other socioeconomic factors (Ahlers et al., 2016; Kapfer & Potts, 2012), but this does not appear to be an important factor in the annual harvest of bobcats in Wisconsin based on our models. Our top models ('Bobcat Population,' 'Bobcat Population x Hunter Participation,' and 'Bobcat Population + Kittens Harvested + Total Incidental Catch') instead indicated the importance of permits issued and the current population, with harvests increasing as permits decreased. Contrary to furbearer research in other areas (e.g., Elsken-Lacy et al., 1999; Gehrt et al., 2002), none of our models that included pelt price were relevant to annual harvest. This may be partly due to quotas being set at one bobcat, which limit the financial gains that can be earned through bobcat hunting. Kapfer and Potts (2012) suggested that decreasing permits in Wisconsin have increased the perceived value of an opportunity to participate in a hunt and disassociated bobcat hunting from being a source of income from pelts. Instead, bobcat hunters show an increasing preference for individuals with trophy traits (older age, and males over females) to make into taxidermy mounts and less frequently for selling pelts (Allen et al., 2018), making bobcat hunting in Wisconsin more closely akin to trophy hunting. In addition, the bobcat population and hunter success have been growing over time (Allen et al., 2018), potentially leading to a perception of an increased likelihood of success. This perception could be partially driven because even though the number of available permits has decreased by an order of magnitude, the number of bobcats harvested has increased over time.

Various factors have contributed to changes in the management of bobcats in Wisconsin, resulting in a decreasing availability of permits and an increasing bobcat population, and have led to a natural study about how the availability of permits issued affects wildlife populations and hunter interest and participation. Over the last two decades, the availability of permits has decreased while hunter participation and success rate have increased. Since this trend is contrary to the generally stable or declining trend in hunter interest across North America (Miller & Vaske, 2003; Winkler & Warnke, 2013), it may contribute an important principle to increasing hunter interest. In addition, hunts that are restricted to a very small number of permits can increase the perceived value and therefore increase the revenue produced (Loveridge, Reynolds, & Milner-Gulland, 2006), although this is also likely dependent on the perceived value or charisma of species and may not be applicable to all species. The downside of decreased permits and a shift to a trophy hunt is that the number of people who can hunt in a given year is limited and can lead to a substantial increase in the wait to obtain a permit (e.g., the current wait time is six years in Wisconsin to receive a bobcat permit). However, because wildlife agencies are responsible for public trust, managers should strongly consider these consequences before implementing similar regulations.

Acknowledgments

This project was funded by Federal Aid in Wildlife Restoration Grant WI W-160-R, the Wisconsin Department of Natural Resources, and the Department of Forest and Wildlife Ecology at the University of Wisconsin, Madison. We thank S. Hull, B. Dhuey, R. Rolley, D. MacFarland, J. Rees, and C. Dennison for their support, and two anonymous reviewers for comments that greatly improved the manuscript.

ORCID

Maximilian L. Allen http://orcid.org/0000-0001-8976-889X

References

Ahlers, A. A., Heske, E. J., & Miller, C. A. (2016). Economic influences on trapper participation and per capita harvest of muskrat. *Wildlife Society Bulletin*, *40*, 548–553. doi:10.1002/wsb.696

Allen, M. L., Roberts, N. M., & Van Deelen, T. R. (2018). Hunter selection for larger and older male bobcats affects annual harvest demography. *Royal Society Open Science*, *5*, 180668. doi:10.1098/rsos.172483

Allen, M. L., Wallace, C. F., & Wilmers, C. C. (2015). Patterns in bobcat (Lynx rufus) scent marking and communication behaviors. *Journal of Ethology*, *33*, 9–14. doi:10.1007/s10164-014-0418-0

Anderson, S. H. (2002). *Managing our wildlife resources*. Upper Saddle River, NJ: Prentice Hall.

Arrow, K. J. (1959). Toward a theory of price adjusment. In Abromovitz, M. et al. (Eds.) *The Allocation of Economic Resources* (pp. 41–51). Stanford, CA: Stanford University Press.

Bailey, T. N. (1974). Social organization in a bobcat population. *Journal of Wildlife Management*, *38*, 435–446. doi:10.2307/3800874

Balme, G. A., Hunter, L., & Braczkowski, A. R. (2012). Applicability of age-based hunting regulations for African leopards. *PLoS One*, *7*(4), e35209.

Boxall, P. C., Watson, D. O., & McFarlane, B. L. (2001). Some aspects of the anatomy of Alberta's hunting decline: 1990-1997. *Human Dimensions of Wildlife*, *6*, 97–113. doi:10.1080/108712001317151949

Burnham, K. P., & Anderson, D. R. (2003). *Model selection and multimodel inference: A practical information-theoretic approach*. New York, NY: Springer.

Clark, C. W., & Tait, D. E. (1982). Sex-selective harvesting of wildlife populations. *Ecological Modelling*, *14*, 251–260. doi:10.1016/0304-3800(82)90021-7

Creed, W. A., & Ashbrenner, J. E. (1975). *Status report on Wisconsin bobcats*. Madison, Wisconsin, USA: Department of Natural Resources.

Decker, D. J., & Chase, L. C. (1997). Human dimensions of living with wildlife: A management challenge for the 21st century. *Wildlife Society Bulletin*, *25*, 788–795.
DeVos, J. C., Shroufe, D. L., & Supplee, V. C. (1998). Managing wildlife by ballot initiative: The Arizona experience. *Human Dimensions of Wildlife*, *3*(2), 60–66. doi:10.1080/10871209809359126
Ebeling-Schuld, A. M., & Darimont, C. T. (2017). Online hunting forums identify achievement as prominent among multiple satisfactions. *Wildlife Society Bulletin*, *41*, 523–529. doi:10.1002/wsb.796
Elsken-Lacy, P., Wilson, A. M., Heidt, G. A., & Peck, J. H. (1999). Arkansas gray fox fur price-harvest model revisited. *Journla of the Arkansas Academy of Science*, *53*, 50–54.
Enck, J. W., Decker, D. J., & Brown, T. L. (2012). Status of hunter recruitment and retention in the United States. *Wildlife Society Bulletin*, *28*, 817–824.
Festa-Bianchet, M. (2003). Exploitative wildlife management as a selective pressure for the life-history evolution of large mammals. In M. Festa-Bianchet & M. Apollonio (Eds.), *Animal behavior and wildlife conservation*, 191-207. Washington DC, USA: Island Press.
Gehrt, S. D., Hubert, G. F., & Ellis, J. A. (2002). Long-term population trends of raccoons in Illinois. *Wildlife Society Bulletin*, *30*, 457–463.
Hammitt, W. E., McDonald, C. D., & Noe, F. P. (1989). Wildlife management: Managing the hunt versus hunting experience. *Environmental Management*, *13*, 503–507. doi:10.1007/BF01867684
Heberlein, T. A. (1991). Changing attitudes and funding for wildlife: Preserving the sport hunter. *Wildlife Society Bulletin*, *19*, 528–534.
Heberlein, T. A., & Kuentzel, W. F. (2002). Too many hunters or not enough deer? Human and biological determinants of hunter satisfaction and quality. *Human Dimensions of Wildlife*, *7*, 229–250. doi:10.1080/10871200214753
Hiller, T. L., Etter, D. R., Belant, J. L., & Tyre, A. J. (2011). Factors affecting harvests of fishers and American martens in northern michigan. *Journal of Wildlife Management*, *75*, 1399–1405. doi:10.1002/jwmg.1693
Kapfer, P. M., & Potts, K. B. (2012). Socioeconomic and ecological correlates of bobcat harvest in Minnesota. *Journal of Wildlife Management*, *76*, 237–242. doi:10.1002/jwmg.284
Klepinger, K. E., Creed, W. A., & Ashbrenner, J. E. (1979). Monitoring bobcat harvest and populations in Wisconsin. In Lynn Giroux Blum and Peter C. Escherich (Eds.) *Proceedings of the 1979 bobcat research conference* (pp. 23–26). Washington, DC: National Wildlife Federation.
Kohn, B. (1978). *Winter severity index for central Wisconsin*. Madison, Wisconsin, USA: Department of Natural Resources.
Larivière, S., & Walton, L. R. (1997). Lynx rufus. *Mammalian Species*, *563*(563), 1–8. doi:10.2307/3504533
Leopold, A. (1986). *Game management*. Madison, Wisconsin, USA: University of Wisconsin Press.
Loveridge, A. J., Reynolds, J. C., & Milner-Gulland, E. J. (2006). Does sport hunting benefit conservation? In D. MacDonald & K. Service (Eds.), *Key topics in conservation biology* (pp. 222–238). Malden, MA: Blackwell.
Manfredo, M. J., Teel, T., & Bright, A. (2003). Why are public values toward wildlife changing? *Human Dimensions of Wildlife*, *8*, 287–306. doi:10.1080/716100425
Manfredo, M. J., Teel, T. L., Sullivan, L., & Dietsch, A. M. (2017). Values, trust, and cultural backlash in conservation governance: The case of wildlife management in the United States. *Biological Conservation*, *214*, 303–311. doi:10.1016/j.biocon.2017.07.032
Mech, L. D. (2010). Considerations for developing wolf harvesting regulations in the contiguous United States. *Journal of Wildlife Management*, *74*, 1421–1424. doi:10.2193/2009-540
Miller, C. A., & Vaske, J. J. (2003). Individual and situational influences on declining hunter effort in Illinois. *Human Dimensions of Wildlife*, *8*, 263–276. doi:10.1080/716100421
Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., Heisterkamp, S., & Van Willigen, B. (2018). *nlme: Linear and nonlinear mixed effects models. R package version 3*.1-139. Retrieved from https://CRAN.R-project.org/package=nlme
Rasker, R., Martin, M. V., & Johnson, R. L. (1992). Economics: Theory versus practice in wildlife management. *Conservation Biology*, *6*, 338–349. doi:10.1046/j.1523-1739.1992.06030338.x

Roberts, N. M., & Dennison, C. C. (2017). *Bobcat population analyses*. Madison, Wisconsin, USA: Department of Natural Resources.

Rolley, R. E., Kohn, B., & Olson, J. (2001). Evolution of Wisconsin's bobcat harvest management program. In A. Woolf, C. Nielsen, & R. Bluett (Eds.), *Proceedings of the Symposium on Current Bobcat Research and Implications for Management* (pp. 61–66). Nashville, TN: Wildlife Society.

Ryan, E. L., & Shaw, B. (2011). Improving hunter recruitment and retention. *Human Dimensions of Wildlife*, *16*, 311–317. doi:10.1080/10871209.2011.559530

Stedman, R. C., Bhandari, P., Luloff, A. E., Diefenbach, D. R., & Finley, J. C. (2008). Deer hunting on Pennsylvania's public and private lands: A two-tiered system of hunters? *Human Dimensions of Wildlife*, *13*, 222–233. doi:10.1080/10871200802010513

Winkler, R., & Warnke, K. (2013). The future of hunting: An age-period-cohort analysis of deer hunter decline. *Population and Environment*, *34*, 460–480. doi:10.1007/s11111-012-0172-6