Why does the regulated harvest of black bears affect the rate of human-bear conflicts in New Jersey?

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ABSTRACT   Humanity has a miserable track record in conserving large carnivores: from Paleolithic hunters skinning the enormous cave lion 15,000 years ago to the contemporary loss of the marsupial Tasmanian tiger. Today, several iconic members of the order *Carnivora* are on the brink of extinction (Amur leopards, Asiatic cheetahs), and over 75% of the world's 31 large carnivore species have experienced alarming population declines, often directly from human persecution. Yet, several species of large predators have dramatically rebounded (European gray wolf, American black bear) in the most unlikely of places: heavily human-dominated landscapes. For example, the black bear population in northwestern New Jersey (NJ), the state with the highest human densities in the United States, has exponentially increased over sixfold in just 15 years. During this period of unprecedented suburban sprawl in NJ there have been over 26,500 reported human-bear interactions including seven attacks on humans and one human fatality. Given accelerating anthropogenic landscape transformation, there simply are not enough large tracts of wildlands remaining to alone support expanding bear populations. Thus, American black bear conservation in the Anthropocene may ultimately depend upon society's tolerance for this large carnivore in areas where people live, work, and recreate. In an effort to curb bear population growth and reduce conflicts, the first regulated NJ black bear harvest in over three decades was held in 2003 resulting in an acrimonious public debate. How can objective population ecology help us make informed decisions about management actions that elicit such strong emotional responses among different stakeholder groups?

LEARNING OUTCOMES

Students will evaluate how sex, age-class, and behavior (problem vs. normal) affect the probability that black bears in northwestern NJ die from harvest, lethal control, and other causes of mortality like vehicle strikes. Given these results, students will then propose possible explanations for the observed correlation between bear harvest rates and subsequent declines in nuisance bear behaviors reported. Informed by this remarkable dataset comprised of over 3,500 individual bears collected over 33 years, students will ultimately have a meaningful discussion about whether a carefully regulated bear harvest should be included in an integrated management strategy to conserve American black bears.

CLASSROOM TESTED? YES

INTRODUCTION

Large, terrestrial predators (e.g., wolves, big cats, and bears) are some of humanity's most beloved animals. Ironically, they are also some of our planet's most imperiled species (Slide #2) as 24 of the 31 largest carnivore species are experiencing population declines, and they currently occupy an average of only 47% of their historical ranges [1]. This is especially disconcerting to ecologists as the functional removal of apex predators can trigger trophic cascades in food webs resulting in unanticipated and far-reaching ecological consequences [2] (Slide #3). Surprisingly though, populations of several species of large carnivores have stabilized

and are increasing in landscapes that have been heavily transformed by humans such as the European gray wolf (*Canis lupus*) [3] and the American black bear (*Ursus americanus*) [4] (Slide #4). Black bears were almost extirpated in New Jersey (NJ), United States, during the 1950s reduced to less than an estimated 100 individuals. Yet the population recovered to 450–500 bears by the mid-1990s, and then exponentially increased in abundance and spatial range reaching 3,200–3,400 bears by 2010, with densities in some areas exceeding 1.3 bears/km² [5] (Slide #5).

Black bears are opportunistic generalists that exhibit high behavioral plasticity; they are remarkably capable of exploiting human-derived food sources such as garbage, agricultural crops, ornamental fruit trees, apiaries, livestock, bird feeders, pet food, etc. [6]. Black bear recovery in NJ coincided with a rapidly increasing human population and a shift in settlement patterns toward sprawling suburban communities (Slide #6). Since 2001, the New Jersey Division of Fish and Wildlife (NJDFW) has spent over US$9 million on black bear management, responding to over 26,500 human-bear interactions, including >1,400 incidents of verified property damage, >400 livestock kills, >250 pet attacks and/or kills, and seven human attacks, including one fatality (Slide #7). In their comprehensive black bear management report, NJDFW concluded that this level of human-bear conflict is both culturally and fiscally unsustainable [7]. With large, potentially dangerous predators, the cultural carrying capacity (the number of black bears humans will tolerate) is often much lower than the ecological carrying capacity (the number of black bears the environment can support) [8]. Given the robust recovery of black bears across the Mid-Atlantic United States, conservation efforts must now pivot from facilitating population growth toward shaping both bear and human behaviors to promote coexistence in shared landscapes. By reducing human-bear conflicts, we can ultimately bolster the long-term viability of this species by increasing the abundance of bears local stakeholders will tolerate outside of protected areas [7].

In an attempt to curb bear population growth, reduce conflicts with humans, and achieve a bear population that is culturally acceptable, NJDFW reinstated a limited, lottery-based, six-day black bear hunt in December 2003—the first such harvest in NJ in over three decades. Following objections by some stakeholder groups (Slide #8), a harvest moratorium occurred in 2004, the hunt was reopened in 2005, then closed again between 2006 and 2009, and has been reopened since 2010. For those familiar with experimental design, this intermittent harvest represents a treatment that allows us to test the effects of bear harvest on nuisance complaints reported in this social-ecological system. It is important to note that this harvest is adaptive in that quotas, i.e. harvest limits, are set annually based on the estimated rate of population growth, and the hunt is immediately closed if that quota is reached prior to the close of the six-day black bear hunting season. Further, recreational harvest is just one component in NJDFW's integrated black bear management plan which also includes educational outreach programs (detailed here: http://www.state.nj.us/dep/fgw/bearfacts_education.htm) and an incident-response protocol for managers and public safety officers (described below, and detailed here: http://www.nj.gov/dep/fgw/bearfacts_resandmgt.htm). For example beginning in 2008, NJDFW began heavily investing in bear educational resources including informational brochures, classroom kits, and over 100 public presentations annually reaching over 10,000 in attendance [7].

Our research team, comprised of bear managers from NJDFW, researchers and donors from the non-profit organization Bear Trust International, and population ecologists from Utah State University, sought to understand if the socially divisive management actions harvest and lethal control (i.e., humanely euthanizing threatening bears), when coupled with existing educational and incident response protocols, were effective in reducing human-bear conflicts (Slide #9) [9]. Our analyses were guided by the following three, big questions:

1. At what rates do black bears die from the following mortality causes: a) regulated bear harvest, b) lethal control by managers, and c) all other sources combined (e.g., vehicle strikes, illegal kills, intraspecific infanticide, etc.)?

2. How does bear sex (female or male), age-class (cub, yearling, or adult), and behavior (problem or normal bear) affect the probability of dying from the different causes of mortality listed above? In other words, if you are an adult male bear, are you more or less likely to be harvested than a yearling male? If you become a "problem" bear, are you more or less likely to be lethally controlled by managers?

3. Is there a relationship between the rates of bears harvested and lethally controlled in year *t* and the number of nuisance complaints that are reported in year *t* + 1?

CASE EXAMINATION

Data collection

From 1981 to 2014, NJDFW personnel conducted 5,185 black bear captures, marking 3,533 different individuals with unique metal ear tags (1,614 females, 1,919 males), including 1,344 cubs of the year, 877 yearlings, and 1,312 adults (Slide #10). NJDFW employs a standardized incident-response framework for responding to bears deemed a threat to human safety, agricultural crops and/or property, or exhibiting nuisance behavior. All captured bears are designated by NJDFW managers as one of the following behavioral categories: I) Threat: including human, livestock, and unprovoked pet attacks, home entries, and agricultural/property damage >US$500; II) Nuisance: including habitual visits to garbage containers, dumpsters and/or bird-feeders, and property damage <US$500; and III) Normal: including bears observed by hunters, hikers, or campers in bear habitat, or dispersing animals that wander through rural and suburban communities. Threatening bears are lethally controlled as soon as possible throughout the year. Nuisance bears, if trapped, are aversively conditioned on-site. Aversive conditioning entails using non-lethal stimuli, including rubber buckshot, pyrotechnics, and bear dogs, to ensure that nuisance bears associate undesirable behaviors (e.g., foraging in anthropogenic habitats) with a negative experience. NJDFW received 26,582 incident reports from the general public between 2001 and 2013 and categorized those as 2,277 Threats, 12,013 Nuisances, and 12,292 Normal interactions. The cause of mortality was later documented for 1,338 of the 3,533 captured and marked individuals, consisting of 556 hunter harvests, 396 management mortalities (158 euthanized by managers and police officers, 238 lethally controlled with agricultural depredation permits), and 386 other mortalities (primarily composed of 271 vehicle strikes and 58 illegal kills). Agricultural depredation permits are granted to farmers, livestock producers, and apiarists who sustain >US$500 in loss, as verified by NJDFW bear managers, to personally control problem bears. All controlled bears are reported to NJDFW and included in the analyses herein.

Estimating cause-specific mortality probabilities

To address questions 1 and 2, we employed a demographic modeling tool used to estimate survival and cause-specific mortality rates of mobile species, aptly named, capture-mark-recapture (CMR) methods [10] (Slide #11). The technique CMR initially allows us to estimate the probability that an animal, a black bear in our case, previously marked with a unique metal ear tag will be recaptured on another trapping occasion or physically recovered if it dies. Based on these "detection probabilities," we then estimate the probability that a bear will transition from an "Alive State" to one of our three defined dead states (Harvested, Lethally Managed, or Dead All Other Causes) in any given year. This probability of transitioning to a dead state is one technique population ecologists employ to estimate "cause-specific mortality rates" of organisms as a function of sex, age, and physical and/or behavioral traits. For example, we now have an empirically derived estimate of the probability that an adult male will die from harvest in a given year during the study period (Slide #12).

Estimating if there is a correlation between harvest and lethal control rates in year t, and problem behaviors reported in year t + 1

To achieve objective 3, we first plotted all bear behaviors reported (i.e., Threat, Nuisance, and Normal), as well as our cause-specific mortality rates (described above) for each year we had reporting data (2001 through 2013; Slide #13). We also plotted the proportion of each bear behavior relative to other behaviors during these same years (Slide #14). We then used the statistical tool linear regression to determine if there was a significant (a = 0.05) relationship between the rates of bears dying from all causes combined (total mortality) in year t and the number of nuisance behaviors reported in year t + 1. Additionally, we used the same methods to evaluate if just harvest and lethal control rates in year t explained variation in the number of nuisance behaviors reported during year t + 1 (Slide #15). Note, these rates were coupled to assess the additional influence of harvest on the background, inter-annual lethal control rates, and ultimately, increase our sample size (see Teaching Notes for more detail).

A FINAL NOTE ON "SIGNIFICANCE" AND UNCERTAINTY IN SOCIAL-ECOLOGICAL SYSTEMS

In the ensuing discussion it is important to remind students that a defining attribute of the scientific process is an explicit attempt to quantify uncertainty. For example, we present a "significant" correlation between increasing harvest and lethal control rates and subsequent declines in nuisance behaviors reported by expressing a low calculated probability (i.e., p-value = 0.028) which informs the audience that these data are highly unlikely if the null hypothesis is true, i.e., there is no relationship between our predictor and response

variables. That said, there is much we do not understand as ecological drivers (e.g., increasing bear densities, climate variability) interact in complex ways with the social dimensions inherent to the system (e.g., the probability that a person who experiences a negative bear interaction reports this interaction). As an example, untangling how much of the observed decline in nuisance bear behaviors is due to humans altering their behavior in response to educational outreach versus bears adapting to the presence of a new predator in the system, i.e., the human hunter, is likely inextricably confounded with this dataset. However, it could be addressed with the collection of additional data within a well-executed experimental design.

CONCLUSION

The conservation of large, ecologically-influential carnivores necessitates prioritizing innovative interventions outside of protected areas as coexistence between humans and carnivores likely represents the only realistic way forward in ensuring carnivore persistence in heavily transformed, novel social-ecological systems [11]. Optimizing human-carnivore coexistence in these shared landscapes demands mutualistic coadaptation, i.e., both humans and carnivores learning from experience and altering their behaviors to minimize negative impacts on each other [12] (Slide #18).

CASE STUDY QUESTIONS

1. Examine our tables of cause-specific mortality estimates to answer the following questions:

   a. How does the age-class (cub, yearling, and adult) and sex of the black bear (female vs. male) interact to influence its probability of being harvested? Remember to examine whether 95% confidence intervals overlap to determine if differences are significant. (Slide #16)

   b. What is the dominant source of mortality for young bears (cubs and yearlings) in this human-dominated landscape? Why do you think this category is so high? (Slide #16)

   c. How does behavior affect the probability that black bears in northwestern NJ are harvested and lethally controlled? (Slide #17)

2. Examine our temporal line/bar graph on Slide #13: Do you see a relationship between nuisance

behaviors reported and the implementation of harvest in years 2003, 2005, and 2010–2013?

3. Examine our temporal line graph on Slide #14: In what year does the proportion of normal behaviors reported begin increasing relative to problem behaviors (that begin decreasing at this inflection point)? What event occurred during this time, and what are the implications for bear management?

4. Examine our linear regressions in Slide #15: Is the change in nuisance behaviors reported in year $t + 1$ more strongly correlated with total mortality in year t or harvest + management mortality rates in year t?

5. Provide three hypotheses explaining the observed correlation between implementing the new bear harvest and subsequent declines in nuisance bear behaviors reported. They do not have to be "mutually-exclusive," i.e., two or more hypotheses could be occurring simultaneously.

AUTHOR CONTRIBUTIONS

Conceptualization	JDR, LMA, MJRH
Methodology	LMA, JDR
Software	JDR, LMA
Validation	MJRH, PCC
Formal Analysis	JDR, LMA
Investigation	PCC, JDR
Resources	PCC, MJRH, LMA
Data Curation	PCC, JDR
Writing—Original Draft	JDR, LMA
Writing—Reviewing and Editing	MJRH, PCC
Visualization	JDR, LMA, MJRH
Supervision	LMA, MJRH, PCC
Project Administration	LMA, MJRH, PCC
Funding Acquisition	LMA, MJRH, PCC, JDR

SUPPORTING INFORMATION

Teaching Notes:

Article title: Why does the regulated harvest of black bears affect the rate of human-bear conflicts in New Jersey?

Questions about the Teaching Notes:

Contact the authors for enquiries about teaching this case, including answers to any questions posed by the Case, the Teaching Notes, or Case Study Questions.

Slides:

Article title: Why does the regulated harvest of black bears affect the rate of human-bear conflicts in New Jersey?

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