Mammalian Biology 81 (2016) 290–294

Contents lists available at ScienceDirect

Mammalian Biology

journal homepage: www.elsevier.com/locate/mambio

Original investigation

Mortality in the Eurasian lynx population in Croatia over the course of 40 years

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ARTICLE INFO

Article history:
Received 3 September 2015
Accepted 3 February 2016
Handled by Francesco Ferretti
Available online 16 March 2016

Keywords:
Eurasian lynx
Mortality
Poaching
Hunting
Attitudes

ABSTRACT

The combination of intensive persecution, habitat loss and prey deficiency led to the extinction of Eurasian lynx (*Lynx lynx*) in the Dinaric Mountains at the beginning of the 20th century. In 1973, the population was re-established by reintroducing animals from the Slovakian Carpathian Mountains into Slovenia, from where the animals spread into Croatia and Bosnia and Herzegovina. Since the end of the 20th century the reintroduced population has been decreasing, leading us to investigate the principal causes of mortality. Understanding the causes of the declining lynx population in Croatia and elsewhere is important not only in its own right but also because few studies have examined how large carnivore populations have fared under different management regimes. After reintroduction, the first dead lynx was recorded in Croatia in 1978, and from that year until 2013 a total of 232 deaths were recorded. Annual mortality during this period averaged 6.4 deaths per year, ranging from 0 to 17. The number of dead lynxes found every year in the period before the legal protection (1978–1998) was significantly higher than the number of dead animals found in the period after the legal protection (1998–2013). The vast majority of deaths were human-related (92.7%), with only 2.1% not human-related; while the cause of the remaining 5.2% of deaths was undetermined. Shooting was the most dominant cause of death (73.7%), with significantly more males being killed by shooting than females, and significantly more animals shot before the legal protection. Between 1978 and 1998, the year when the lynx became legally protected in Croatia, 10 deaths due to poaching were recorded, accounting for 5% of all deaths in that period and an average of 0.48 poaching cases per year. During 1999–2013, 18 poaching deaths occurred, accounting for 60% of all deaths in that period and an average of 1.2 poaching cases per year. Our findings suggest that the synergy of human-induced mortality, concomitant reduction in genetic variation and possibly prey deficiency may be the principal factors behind the decline in the reintroduced lynx population in Croatia since the end of the 20th century.

Introduction

The combination of habitat loss, prey depletion and intensive persecution (Breitenmoser et al., 1998) led to the extinction of Eurasian lynx (*Lynx lynx*) from the Dinaric Mountains at the beginning of the 20th century. In 1973, Slovenian hunters organized the reintroduction of six animals from Slovakia into Slovenia in order to revive lynx trophy hunting. The newly established population encountered a favorable habitat and abundant prey, so the population rapidly expanded. By 1974, lynx had already appeared in Croatia and by 1980, they were observed in Bosnia and Herzegovina (Čop, 1987; Frković, 2001).

Lynx hunting began in Slovenia and Croatia in 1978 (Frković, 2001), and it continued in Croatia until 1998, even after the animal's legal status in Croatia changed in 1982 from game to protected species. From 1982 until 1998, annual hunting quotas were issued that limited total mortality to 7–14 animals per year (Frković, 1998). In 1998, the lynx was listed as a strictly protected species, and hunting quotas were no longer issued.

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http://dx.doi.org/10.1016/j.mambio.2016.02.002
1616-5047/

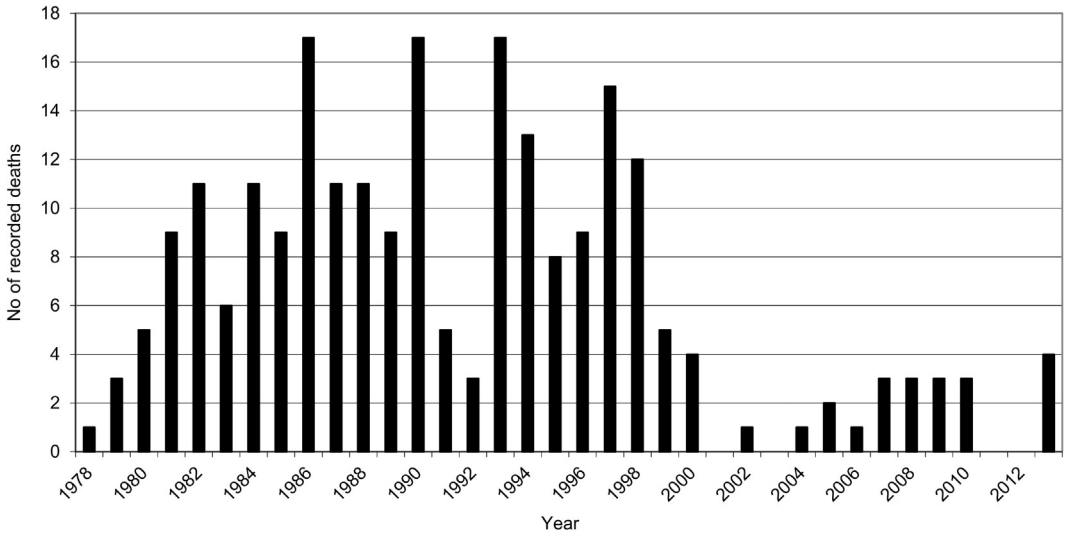

Fig. 1. Annual lynx mortality in Croatia based on data from a national monitoring program, 1978–2013.

Evidence suggests that after reintroduction, the lynx population enjoyed rapid population growth and range expansion until the late 1980s, after which it probably stabilized until the late 1990s. Then, according to field studies, the population began to decrease at the end of the 20th century (von Arx et al., 2004; Gomerčić et al., 2009, 2010; Sindičić et al., 2010a), a hypothesis corroborated by molecular genetic analysis indicating low effective population size, considerable inbreeding and low genetic diversity (Sindičić et al., 2013).

Several factors may be contributing to this decrease, which threatens population survival. These factors may include habitat fragmentation, prey base depletion, poaching and traffic-related mortality, as well as a possible reduction in the fitness of individual animals due to loss of genetic diversity (Sindičić et al., 2013). Indeed, Eurasian lynx live at low densities in large habitats and have low reproductive and population growth rates, making them potentially vulnerable to numerous factors affecting population dynamics. Understanding the causes of the declining lynx population in Croatia and elsewhere is important not only in its own right but also because few studies have examined how large carnivore populations have fared under different management regimes (Linnell et al., 2010).

Therefore the present study investigated the primary drivers of mortality in the Eurasian lynx population in Croatia during the 40 years since its reintroduction, and it assessed the importance of these drivers for long-term population stability. The results provide much-needed insights into factors associated with long-term mortality in a reintroduced population of large carnivores.

Material and methods

Data on mortality of the lynx population in Croatia were collected through a national monitoring program. This includes data on harvest since the reintroduction until the total legal protection, chance observations and mortality of radio collared lynx. Until 2002 a total of 8 lynxes were monitored trough radio-telemetry. The national database included information on cause, date and location of deaths, as well as on the sex and estimated age of the dead animal (categorized as yearling or >1 year old). Since the lynx was declared a strictly protected species in 1998 whenever possible carcasses were collected and examined at the Faculty of Veterinary Medicine, University of Zagreb. A total of 11 necropsies were conducted according to a standard veterinary protocol. When poaching was suspected, as well as in most forensic cases, the entire animal was radiographed to detect fragments of bullets or lead pellets. In several cases, retrieving the body was impossible. We confirmed these cases to be deaths when we had a photograph, tissue from the dead animal body, a destroyed radio collar in the case of a missing radio-tracked animal or a poaching tip from a reliable person or eyewitness.

A Mann–Whitney *U*-test was done to compare the number of dead lynxes found every year between the period before the legal protection (1978–1998) and the period after the legal protection (1998–2013). Chi-square tests were used to test the significance of differences between causes of mortality among sex classes; causes of mortality among age classes; causes of mortality between the period before the legal protection (1978–1998) and the period after the legal protection (1998–2013). The significance of differences between numbers of dead individuals of different age classes in each month was also tested using a Chi-square test.

Results

The first recorded death of a lynx in Croatia since reintroduction was in 1978 by shooting. Over the period from 1978 to 2013, 232 deaths were recorded. Of these, 110 (47.4%) were females, while 88 (37.9%) were males and the remaining 34 (14.7%) were of undetermined sex. Most of these animals were older than 1 year ($n = 155$, 66.8%), with the minority younger than 1 year ($n = 68$, 29.3%) and nine of undetermined age (3.9%).

Annual mortality averaged 6.4 lynx per year, ranging from 0 to 17 per year (Fig. 1). Of the 232 dead lynx over the entire 36-year study period, the vast majority (202) occurred between 1978 and 1998, when the last yearly hunting quota was issued. During this 20-year period, annual mortality averaged 9.6 per year and was significantly greater than that recorded in 1998–2013 ($p < 0.01$). Between 1998 and 2013, recorded mortality was quite sparse, with only 30 deaths in 15 years; annual mortality averaged 2.0 per year and ranged from 0 to 5 per year. A drop in mortality in the 1991–1995 period is probably due to the Homeland War in Croatia, because during that time mortality could not be properly monitored.

Analysis of the geographic distribution of recorded lynx deaths in Croatia (Fig. 2) suggests that population range expanded until the late 1980s, after which it remained stable during the 1990s, and then contracted starting around the year 2000. The core lynx habitat