STUDY OF EFFECTS OF SELECTIVE HUNTING ON A BEAR POPULATION THROUGH PVA SIMULATION

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STUDY OF EFFECTS OF SELECTIVE HUNTING ON A BEAR POPULATION THROUGH PVA SIMULATION

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ABSTRACT

STUDY OF EFFECTS OF SELECTIVE HUNTING ON A BEAR POPULATION THROUGH PVA SIMULATION

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Management of big wildlife such as bears can be a difficult task, especially in the face of human-wildlife conflict and demands of the hunting industry. The Brown Bear (*Ursus arctos*) population at Yusufeli County (Artvin, northeastern Turkey) has recently been the focus of scientific, social and economic concerns. This study population of c. 140 individuals occurs within 800 km^2 of forested and alpine land. Legal hunting of male bears was allowed in 2007 after an interval of four years.

This study aims to find out through a population viability analysis the level and frequency of trophy hunting this population can tolerate for the next 50 years. A matrix model with six age-classes for each sex was constructed using observed and literature-based parameter values. RAMAS Metapop was used to simulate four different scenarios where numbers of hunted bears and hunting frequency changes.

The model was highly sensitive to maximum growth rate and adult survival. Interval extinction probabilities for the next 50 years ranged between 0% and 26% depending on the scenario. Viable scenarios (with an extinction probability < 0.05) were only possible with either no trophy hunting or hunting of 4 subadult/adult males and 1 adult female every other year. Legal and illegal hunting jointly impact the bear population in a strong way, and when they occur simultaneously every year, they lead to extinction in the long run. Avoidance of illegal killing and a close supervision of trophy hunting are crucial in the management of this bear population.

Keywords: *Ursus arctos*, Brown Bear, population viability analysis, selective hunting, Artvin

ÖZ

BİR AYI POPULASYONUNDA SEÇİCİ AVLAMA ETKİLERİNİN P.Y.A. SİMÜLASYONU İLE ARAŞTIRILMASI

AĞZITEMİZ, Mehmet Melih
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Ayı gibi büyük yaban hayvanlarının yönetimi özellikle av endüstirisinin istekleri ve insan-yaban hayatı çatışması nedeniyle zor bir iştir. Türkiye'nin kuzeydoğusundaki Artvin ilinin Yusufeli ilçesindeki boz ayı (*Ursus arctos*) populasyonu son zamanlarda bilimsel, sosyal ve ekonomik açılardan ilgi odağı olmuştur. Çalışma odağı, 800 km^{2}'lik ormanlık ve alpin çayırlık alan içinde yaşayan 140 civarında ayıdan oluşan bir populasyondur. Dört yıl aradan sonra 2007 yılında erkek ayıların avlanmasına yasal olarak izin verilmiştir.

Bu çalışma gelecek 50 yıl içerisinde bu populasyonun dayanabileceği trofe avcılık derecesini ve sıklığını populasyon yaşayabilirlik analizi ile bulmayı amaçlamaktadır. Gözlemlerden ve konuyla ilgili yazınlardan elde edilen parametre değerleri kullanılarak her iki cinsiyet için de 6 yaş grubu bulunan bir matris modeli yapılandırılmıştır. Avlanma sayısı ve sıklığı değişen dört farklı senaryonun simulasyonu RAMAS Metapop yazılımı kullanılarak yapılmıştır.

Model, maksimum büyüme oranına ve yetişkinlerin hayatta kalma oranına çokça duyarlıdır. Bu populasyonun 50 yıllık aralık yok olma tehlikesi senaryosuna göre %0 ile %26 arasında değişmektedir. Yaşayabilir (yok olma olasılığı 0.05'den küçük olan) senaryolar ancak trofe avcılığının olmaması halinde veya 2 yılda bir 4 genç/yetişkin erkeğin ve 1 yetişkin dişinin avlandığı trofe avcılığının uygulanması halinde mümkün olabilmektedir. Yasal ve kaçak avlanmanın ikisi birlikte ayı nüfusuna güçlü bir etki yapmaktadır ve bunlar her yıl ve eşzamanlı gerçekleştiklerinde populasyonu uzun dönemde yok olmaya iterler. Yasak avlanmadan kaçınılması ve trofe avcılığının yakından denetlenmesi bu ayı populasyonunun yönetimi için çok önemlidir.

Anahtar Kelimeler: *Ursus arctos*, Boz Ayı, populasyon yaşayabilirlik analizi, seçici avlanma, Artvin

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INTRODUCTION

1.1. Mathematics in Biology

Among all sciences, mathematics is the strongest discipline in its ability to reach exact results. If one can prove a statement, it is always true to say that, if the assumptions in the statement are satisfied, then the result is always achieved anytime, anywhere. This certain knowledge of result is a great treasure. One hopes that this treasure is even greater in natural sciences like biology. Of course being an experimental science, biology also seeks certain knowledge about results to be exact in producing solutions to problems it encounters. In order to achieve this, it needs mathematics to do the job for it. This is why mathematics has gained importance in biology since beginning of the 20th century and many mathematicians, such as G.H. Hardy (1908) who studied theoretical population genetics, has contributed to diverse fields in biology (May 2004).

Mathematics has many branches which might assist different areas of biology. For example, graph theory can be used perfectly to do the abstraction of gene networks, neuron networks, metapopulation networks or in general all network-based structures. Numerical analysis, calculus, differential equations, or algebra can be used to model real world problems, make calculations and if we are lucky in satisfying all assumptions like in a statement, we have the exact knowledge of result. However, we are almost never lucky with these satisfied assumptions, since we lack experimental knowledge and we lack future knowledge since we are human. Nevertheless with our scientific method and with our brains we can attempt to predict the future, and this can make assumptions highly probable to be satisfied. Therefore, we reach not exact results but highly probable outcomes.

1.2. Population Dynamics

Population biology is an area that investigates all aspects of the population or a union of populations, namely a metapopulation, in time. Among these aspects are abundance, structure, genetic composition, movements and habitat use of a population. Specifically, population dynamics is the study of changes in the numbers and age composition of individuals in one or several populations, and biological and environmental processes influencing those changes. It can be a tool to predict about future of the population; it can be of assistance while forming management plans or surely it can be used to improve the pure mathematical theory of population dynamics by using the feedback supplied by biology. Shortly, population dynamics is a whole with two main parts; one of biology (particularly, population ecology), and one of mathematics (particularly, dynamical systems).

It can be useful here to provide some basic concepts in population dynamics. Firstly abundance of a population changes according to the number of births (B), deaths (D), immigrants (I) and emigrants (E). If N(t) shows the number of individuals in year t, then the next year's abundance can be written as:

$$N\ (t + 1) = N\ (t) + B - D + I - E$$

The ratio $N\ (t + 1) / N\ (t)$ provides the finite growth rate of the population for year t and is represented by R (t). Following the previous definition, the expression is now equivalent to $N\ (t + 1) = N\ (t) * R\ (t)$. If one takes R which is a fixed finite growth rate for all years and proceeds with $N\ (t) = N\ (t - 1) * R$, $N\ (t - 1) = N\ (t - 2) * R$, etc. until reaching $N\ (1) = N\ (0) * R$, then the equation $N\ (t) = N\ (0) * R^{t}$, is obtained where R^{t} means t - th power of R. This type of population growth is called geometric in discrete time and exponential in continuous time which is denoted as:

$$N\ (t) = N\ (0) * e^{r * t}$$

Thus, $e^{r} = R$ and r is called the instantaneous growth rate (Begon and Mortimer 1981, Akçakaya et al. 1999).

However, in real life exponential growth takes place only for a short duration or in experiments, like Gause's classical experiments with no competition. Generally intraspecific competition slows down the growth of a population and stops or considerably reduces it at a level called the carrying capacity, which determines the maximum abundance of a population that its ecosystem can support. There are different types of intraspecific competition, but the scramble competiton and the contest competition are generally the most important (Nicholson 1954, Begon and Mortimer 1981, Akçakaya et al. 1999).

In scramble competition there is an equal sharing of resources whereas in contest competition there is an unequal one. Moreover, in scramble competition a strong decrease in abundance occurs after the population exceeds its carrying capacity, while in contest type competition only a slowing down in growth rate takes place even after the population exceeds its carrying capacity considerably (Nicholson 1954, Begon and Mortimer 1981, Akçakaya et al. 1999).

1.3 Effects of Hunting on Natural Population Dynamics

The natural population dynamics of a population of organism is surely its natural dynamics which is free from any human effect. Such effects include all direct and indirect influences, for example hunting, protection, or habitat destruction. Among those influences, hunting may cause population responses that are disproportional to its scale.
Hunting can have many diverse effects on a population’s dynamics, usually in a negative way (Milner et al. 2007). Some can be the following:

- It reduces the growth rate of the population by directly reducing survival rates of hunted age class or stage members

- It may destroy social interactions in the population, thus strongly affecting age or stage specific survival and fecundity rates (Milner et al. 2007)

- It may cause a catastrophic effect that results in an Allee effect which will severely impact the viability of that population (Courchamp et al. 1999, Akçakaya et al. 1999)

Therefore, hunting without serious management plans or measures based on strong scientific facts is usually a death declaration for that population.

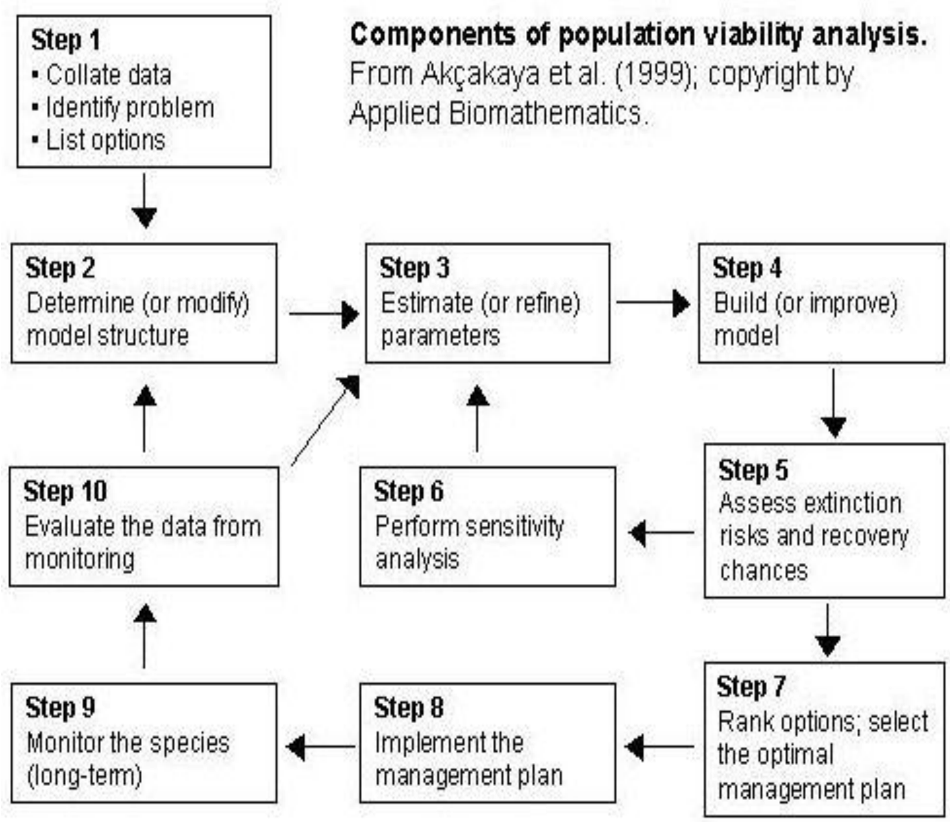
The selective removal of some specific individuals, generally large males for trophy hunting, is among the serious threats to natural population dynamics of the hunted species. It does not only remove individuals at that age or stage class, but also destabilizes social structures which can cause loss of social knowledge, sexually selected infanticide, habitat shifts among reproductive females, and changes in the offspring sex ratio (Milner et al. 2007). Studies on brown bears show that higher mortality of adult males increases the rate of immigration of potentially infanticidal males and this causes higher mortality of cubs (Swenson et al. 2001) and a decrease in female reproductivity (Wielgus and Bunnell 2000).
It is possible to study effects of hunting through modeling (Horino and Miura 2000, Yiming et al. 2003, Nilsson 2004). Sezen et al. (2004) is the first such study in Turkey, where extinction risks were estimated for Turkish mouflon (*Ovis gmelinii anatolica*) under different scenarios of

harvesting for trophy. The study used RAMAS Metapop software and its results suggest that harvesting of more than a few old males per year increases extinction risks within the study period.

1.4. Population Viability Analysis (PVA)

Although there is not a consensus on its definition (Reed et al. 2002), one can define population viability analysis as a process that aims to find the probability of the healthy continuation of that population in the future for some determined time duration. Basically PVA study starts with construction of a model with available data and ends with the evaluation of model results under the scope of identified problem that is aimed to be answered.

In the following figure (Akçakaya et al. 1999), one can see the basic components of a PVA study, which are the step by step details of the procedure.



Components of population viability analysis.
From Akçakaya et al. (1999); copyright by Applied Biomathematics.

Figure 1.1 Components of Population Viability Analysis

Although involving these steps, some studies may include more or less than that according to the context and scope of the study. Mostly the availability of data and ecology of the species determines the most appropriate model structure for a PVA (Boyce 1992, Sezen 2000). One can also include environmental and demographic stochasticity in the model in order to incorporate variability and uncertainty which brings more reality to the model (Burgman et al. 1988, Akçakaya 2000, Sezen 2000). Generally PVA studies are carried out for management purposes and to improve a species' chances of survival, by minimizing the risk of extinction or improving the state of the conditions that a species currently have (Akçakaya et al. 1999).

There are different opinions about the reliability of PVA because of its potential weaknesses due to lack of data or validation (Burgman and Possingham 2000, Brook et al. 2000, 2002). However, for two basic reasons PVA can be very useful even with crude data. With such data, PVA will produce results with a lot of assumptions, but firstly this can be seen as a finding which forces us to think about our shortfalls in data, our knowledge about the study species, and the ecosystem it is a part of. This thinking effort together with a sensitivity analysis can give very valuable and useful findings to realize the broad picture and construct more reliable models. Secondly, it shows the effects of several population management actions that can be put into practice and gives us a chance for comparison between them to select for the most practical and sustainable action (Reed et al. 2002).

PVA has been used for finding solutions to a wide range of problems. One can carry out a PVA in order to understand whether a current population is viable or not (Chapron et al. 2003), to compare the current population abundance with minimum viable population (MVP), to test the population survival under negative effects like habitat loss and hunting pressure (Horino and Miura 2000), or to evaluate the effectiveness of different management practices like reintroduction, translocation and harvesting and to understand whether they have a positive or negative impacts over the population dynamics (Sezen 2000, Sezen et al. 2004).

There are several PVA software packages which are written for different objectives, but they are all suitable for generic applications. Some of these packages such as GAPPS and VORTEX are individual based simulations while INMAT, RAMAS Age and RAMAS Metapop use cohort based approaches (Brook et al. 1997, Sezen 2000). However, it has been shown that the predictions of the different PVA software packages – including RAMAS Metapop – were highly concordant (Brooks et al 2000).

1.5. Study Species : *Ursus arctos*

Brown bear belongs to Order Carnivora, Family Ursidae, Subfamily Ursinae and the genus *Ursus,* which have 4 extant species, namely, *U. arctos, U. americanus, U. maritimus* and *U. thibetanus*, comprising of 16 subspecies on the whole Earth (Pasitschniak-Arts 1993). Although a member of Order Carnivora, the brown bear is an omnivore.

Brown bears are the largest mammals in Turkey but they are smaller than grizzly bears that live in North America (Ambarlı 2006). In size, Turkish brown bears are comparable to smaller grizzly bears in Yellowstone National Park or in the British Colombia (Ciarniello et al. 2003, Ambarlı 2006). The mean weights and body lengths of hunted mature male (and female) bears during 1995 in Artvin were 191.43 kg (and 136.25 kg) and 191.57 cm (and 170.5 cm) respectively. They have a powerful body and various fur colours which vary from pure white to black with dominant occurrence of brown (Pasitschniak-Arts 1993, Jonkel 1994, Ambarlı

2006). Since most bear species hibernate during the lack of readily available food, hibernation of bears, which is known as “winter sleep” that defines the dormant period in winter, begins between October and December and ends with spring arousal between March and May (Pasitschniak-Arts 1993, Craighead 2000). Brown bears are polygamous and breeding occurs from mid-May to July, then the young are born from January to March (Pasitschniak-Arts 1993, Craighead 2000, Ambarlı 2006).

Figure 1.2 A brown bear from Artvin, Turkey

Brown bears eat a wide range of food resources but in Turkey they are predominantly herbivores, especially where and when wild fruits and herbs, cultivated fruits and crops are available. Carnivorous intake is usually limited to opportunistic foraging of small mammals and invertebrates. They share their habitats with many animals but have interspecific interactions only with wild boar and wolf (Durmuş 2002, Ambarlı 2006).

Brown bear has a world range that covers large parts of the northern hemisphere (shown in red in Figure 1.4) although it has been exterminated from most of North America and Europe (Pasitschniak-Arts 1993).

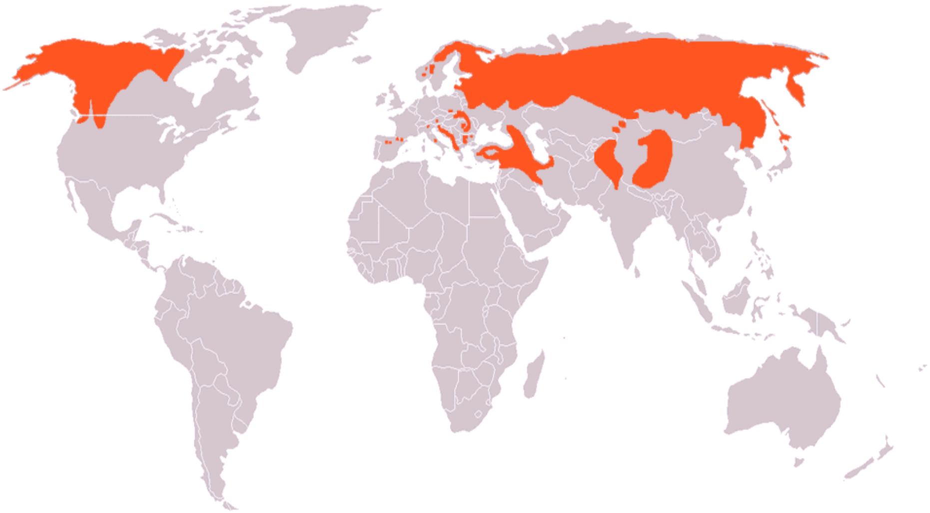


Figure 1.3 Brown bear distribution on the Earth

In Turkey brown bears live in mountainous parts of Turkey (Figure 1.5) although it does not occur any more in suitable habitat in most western and southern provinces (Turan 1984, Ambarlı 2006).

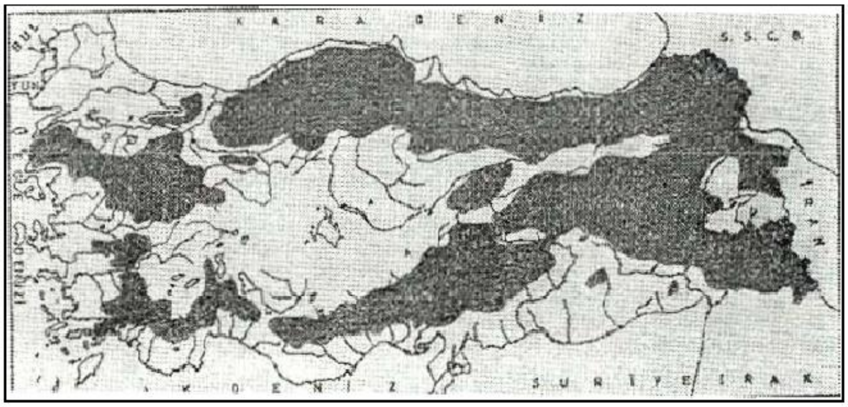


Figure 1.4 Brown bear distribution in Turkey (from Turan 1984)

1.6.Scope and Aim of This Study

This study focuses on a relatively well known population of brown bears at Yusufeli (Artvin) that are known to be the target of both legal and illegal hunting activity (Ambarlı 2006, Ambarlı and Bilgin 2008). After several years of a ban, this population was opened to legal trophy hunting in late 2007.

In this study it is aimed to find an answer to the question "How the brown bear population in Yusufeli would be affected under different future hunting scenarios?" To obtain a result, an age-structured population model is constructed by using available data and RAMAS Metapop software (Akçakaya and Root 2002).

CHAPTER 2

MATERIALS AND METHODS

2.1. Study Area

The study area is situated in the northern half of Yusufeli County (Artvin) and covers most of the Barhal watershed. This area is identical with the study area of Ambarlı (2006) which is situated roughly between 40° 33' to 41° 06' N, 41° 08' and 41° 54' E where several censuses were carried out in the last decade and 3 of them used in this study which were documented in Ambarlı (2006). Its total area is approximately 800 km².

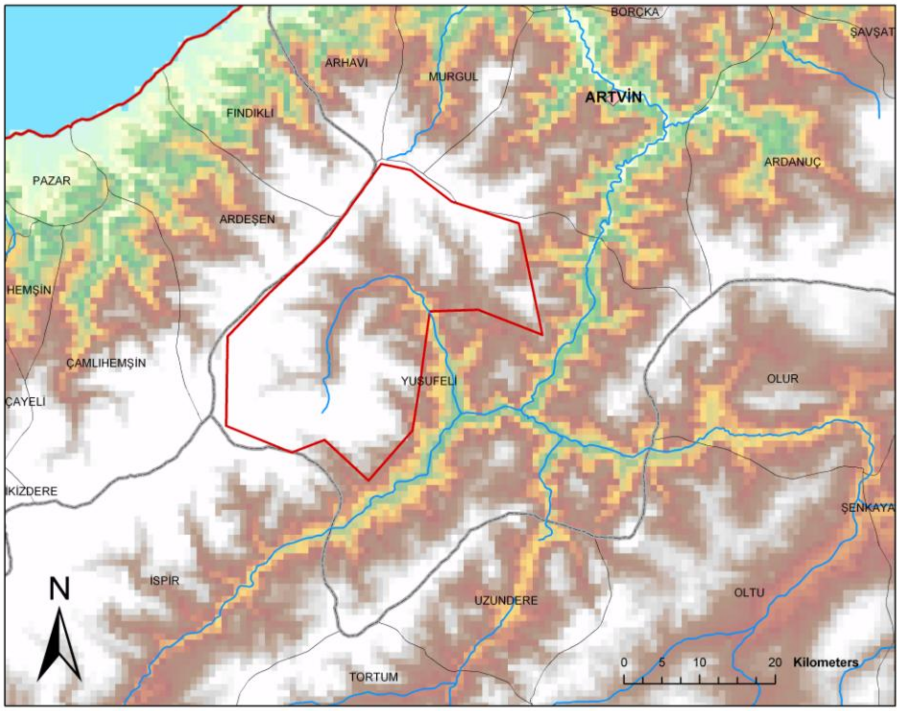


Figure 2.1 Red polygon denotes the study area

The area, which is bounded by Kaçkar Mountains in the north and River Çoruh in the south, has altitudes between the ranges from 550m to over 3900m. Opposite to dry and warm lower parts, cool and humid conditions with snowy winters reigns at the higher elevations. The vegetation changes accordingly to elevation. Mediterranean scrubland exists near the valley bottoms, continuing with the typical coniferous forests of Blacksea Region as the elevation increases, and finally alpine meadows are widespread near the peaks. The human population density is 13 people per km^2 and nearly 75% of potential bear habitat overlaps human settlements. The area contains forests, human settlements, small farms, orchards and some fragmented pasturelands (Ambarlı and Bilgin 2008).

The study area is not fully isolated from neighbouring land but very high peaks in the north and human settlements and climatic dryness in the south limit habitat suitability, and therefore, enables one to consider the bear population within as a single unit.

2.2. Model Structure and Elements

2.2.1. Model Overview

RAMAS Metapop (Akçakaya and Root 2002) was used to build a population model and then to run simulations. RAMAS Metapop basically uses a Leslie matrix approach which can distinguish between age or stage specific survival and fecundity rates instead of setting all individuals identical in the population. It can also incorporate spatial structure, metapopulation dynamics, density dependence and stochasticity (Brook et al. 1997, Sezen 2000). In this study, the model was run 10000 times for 50 time steps where one time step was 1 year.

2.2.2. Stages

6 age stages are assumed for both males (M) and females (F), which are:

- **Cubs** with age interval [0-1) – (C)
- **Yearlings** with age interval [1-2) – (Y)

- **Subad1** with age interval [2-3) – (S1)
- **Subad2** with age interval [3-4) – (S2)
- **Subad3** with age interval [4-5) – (S3)
- **Adults** with age interval [5-5+) – (A)

It is assumed that only 35 % of female individuals in Subad3 and 90 % of all adults can breed after considering maturation, physical suitability and chance to meet a mate.

2.2.3. Sex Structure

Mating system is polygynous and an adult male is assumed to mate with up to 4 females in one breeding season. Male and female matrices are separated in constructing the stage matrix for elucidating the exact effects of poaching and harvesting scenarios on population dynamics of either sex.

2.2.4. Density Dependence

It is assumed that density dependence affects all vital rates (both survival and fecundity rates) since there is no evidence that only one of them is affected. It is suitable to assume that density dependence is based on the abundances of independent subadults, namely classes Subad2 and Subad3, and adults in the Adult class. Since there are no strong data to formalize the density dependence type of the study population it is assumed it is population specific and of the contest type. Because brown bears have home ranges and are partially territorial, contest type is more suitable than any other conventional density dependence types that are available in the software.

2.2.5. Stage Matrix

Stage matrix includes survival and fecundity rates for the population modelled. Stage matrix with abbreviations of stages is in Table 2.1.

Table 2.1 Stage Matrix

	CF	YF	S1F	S2F	S3F	AF	CM	YM	S1M	S2M	S3M	AM
CF	0	0	0	0	0.17512	0.45504	0	0	0	0	0	0
YF	0.82	0	0	0	0	0	0	0	0	0	0	0
S1F	0	0.90	0	0	0	0	0	0	0	0	0	0
S2F	0	0	0.93	0	0	0	0	0	0	0	0	0
S3F	0	0	0	0.94	0	0	0	0	0	0	0	0
AF	0	0	0	0	0.95	0.96	0	0	0	0	0	0
CM	0	0	0	0	0.17512	0.45504	0	0	0	0	0	0
YM	0	0	0	0	0	0	0.82	0	0	0	0	0
S1M	0	0	0	0	0	0	0	0.94	0	0	0	0
S2M	0	0	0	0	0	0	0	0	0.88	0	0	0
S3M	0	0	0	0	0	0	0	0	0	0.88	0	0
AM	0	0	0	0	0	0	0	0	0	0	0.89	0.92

Figure 2.2 represents the model schematically. Red values (survival rates for females) signify transition probabilities of female individuals from a

previous stage (bottom of the arrow) to the next stage (tip of the arrow). Similarly blue values (survival rate for males) signify male transition probabilities in the same manner. Black values (fecundity rates for both S3F and AF) are the numbers of female or male C stage individuals (i.e. cubs) that a female individual in S3 or A stage gives birth to at that year (Detailed explanation of fecundities are in part 2.2.5.). Those values are placed in the stage matrix as seen in Table 2.1. Stage matrix only has non-zero entries where an arrow exists between the stages; all other entries are zero.

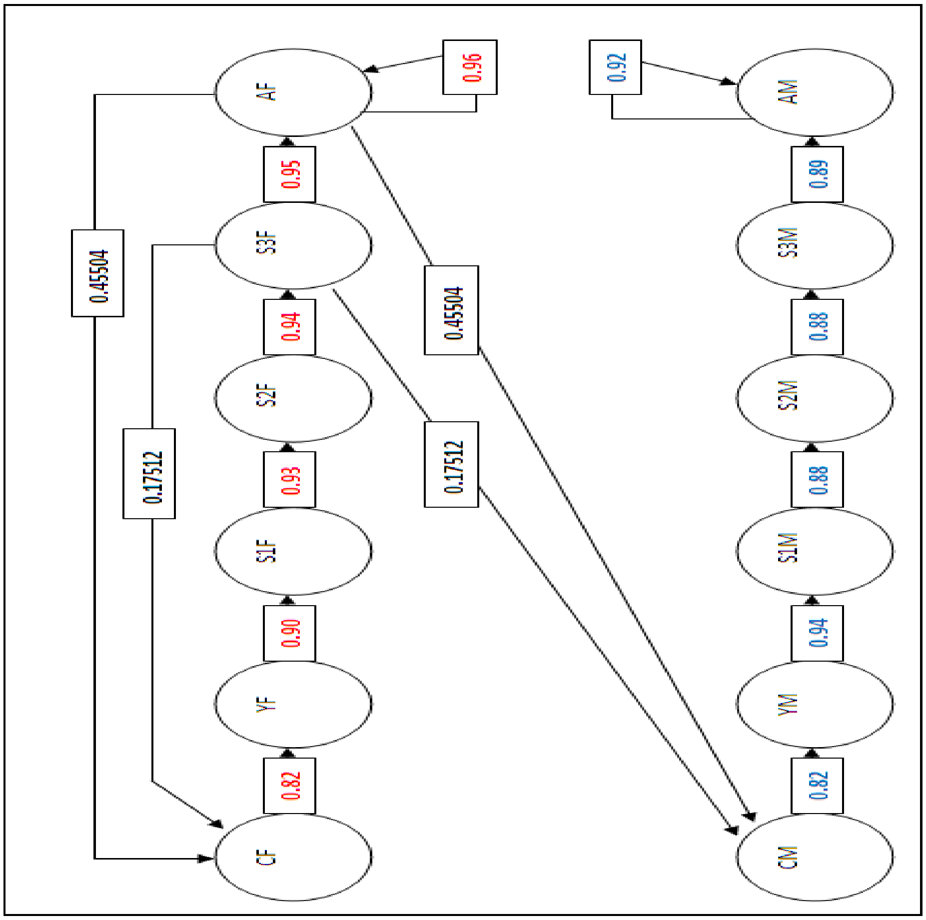


Figure 2.2 Population structure with vital parameter values

Alternative values for survival rates of all individuals, which are identical with North American values, and accordingly Adult and Subad3 fecundities, and most importantly the maximum growth rate Rmax are used for constructing an alternative Scenario0 model. This will be explained later since the model has proven very sensitive to female survival rates and as a result to the growth rate (see Discussion). Firstly even though sensitivity is high for female survival rates here all survival values are changed because the reason that pulls down the female survival rate also is capable of decreasing the other survival rates for males and young, except a specific one that affects only females which is not the general case. Secondly, here an alternative value for growth rate is used since this value is taken as identical to the value computed by the software; therefore the changes in survival and fecundity values requires an accompanying change in maximum growth rate. All alternative values are given in Table 2.2.

Table 2.2 Alternative parameter values for Alternative Model

	Alternative Values
Survival Adult F / M	0.93 / 0.85
Survival Subad3 F / M	0.90 / 0.79
Survival Subad2 F / M	0.90 / 0.79
Survival Subad1 F / M	0.90 / 0.79
Survival Yearling F / M	0.89 / 0.89
Survival Cubs	0.78
Fecundity ADULT	0.44082
Fecundity SUBAD3	0.16590
Rmax (Maximum Growth Rate)	1.0868

Coefficients of 0.90 and 0.35 are used for reducing the whole female population in Adult and Subad3 stages to potentially productive females in those stages respectively. The proportion 1 / 2.25 represents percent of potentially reproductive females with currently no young and therefore available to mate and give birth. The values 0.96 and 0.93 are survival rates for adult females, and 0.95 and 0.90 are survival rates for Subad3 females, for the original and the alternative models respectively. Survival rates in the calculation of fecundities are needed because those females must stay alive throughout that year in order to mate and give birth. After determining the actively productive females in that year, the percentage is multiplied with the mean litter size of 2.37 for obtaining the value "cubs per female per year after surviving that year". This is further multiplied by 0.5 since male and female matrices are separated, and since the male : female sex ratio at birth is 1 : 1. For more details about the above parameters see part 2.3. Fecundity rates for the original and alternative models are calculated as below:

0.45504 = [1 / 2.25] * 2.37 * 0.90 * 0.5 * 0.96 → male (or female) cubs per adult female per year after surviving that year for the original model.

0.44082 = [1 / 2.25] * 2.37 * 0.90 * 0.5 * 0.93 → male (or female) cubs per adult female per year after surviving that year for the alternative model.

0.17512 = [1 / 2.25] * 2.37 * 0.35 * 0.5 * 0.95 → male (or female) cubs per Subad3 female per year after surviving that year for the original model.

0.16590 = [1 / 2.25] * 2.37 * 0.35 * 0.5 * 0.90 → male (or female) cubs per Subad3 female per year after surviving that year for the alternative model.

2.2.6. Standard Deviation Matrix

The basic aim of this matrix is adding environmental stochasticity to the model. Obviously, since one cannot be sure about the oscillations of fecundity and survival values of the species from environmental changes unless there is enough monitoring and real field data from the study area, it is reasonable to acquire this information from some other populations living under similar environmental conditions, if possible. Therefore, data for standard deviations were obtained from Swenson et al. (2001), Wielgus (2002) and Mace and Waller (1998). Nevertheless, the values thus obtained (from Swenson et al. (2001) in particular) were further increased following the precautionary principle (i.e. to avoid underestimating extinction risks) and since the degree of environmental similarity between the study area and those other sites is not known with certainty. Therefore, a coefficient of variance (CV) of 0.30 for survival, and 0.15 for fecundity were used. These values need to be revised when real field data is obtained through future qualified research.

Nevertheless the CV value for fecundity in Wielgus (2002) points to a more variable environment; similarly, the survival figures used here fall within the 95% confidence intervals in Mace and Waller (1998). According to Wielgus (2002) CV for subadult fecundity is 0.26 and CV for adult fecundity is 0.24. Mace and Waller (1998) stated that 95% confidence intervals for survivals of adult and subadults males and females separately, yearlings and cubs for both sexes together are as below:

Adult Male: (0.764 – 0.997)
Adult Female: (0.826 – 0.979)
Subadult Male: (0.638 – 1.000)
Subadult Female: (0.688 – 0.996)
Yearlings: (0.800 – 1.000)
Cubs: (0.626 – 0.949)

The 95% confidence intervals for survivals of all stages in our model are in Table 2.3.

Table 2.3 95% confidence intervals for survival rates

	CF	YF	S1F	S2F	S3F	AF
Lower	0.714	0.841	0.889	0.905	0.921	0.936
Upper	0.926	0.959	0.971	0.975	0.979	0.984
	CM	YM	S1M	S2M	S3M	AM
Lower	0.714	0.905	0.809	0.809	0.825	0.873
Upper	0.926	0.975	0.951	0.951	0.955	0.967

2.2.7. Populations

From the census values in Yusufeli, an average density of 18 bears/100 km² was obtained. Using this density figure, 144 individuals were estimated to occur as initial population within 800 km². As the maximum growth rate, the value calculated by the software itself is used. This value is equal to the dominant eigenvalue of the stage matrix. Here, the growth rate is 1.1251; therefore this population is moderately increasing. This is in line with expectations because the data we used were mostly from growing populations around the world. Scandinavian and Croatian populations, which provide the two basic references for both fecundity and survival rates, have both a growing pattern. Growing populations also exist in North America in general, and since North American parameters were taken into account by averaging them all, it is suitable to assume that a general growing trend holds.

It is not fully certain that the Yusufeli population is growing since there is not enough censuses which would clarify the real situation. However, local people believe that population size of brown bears has increased because the number of conflicts are on the rise (Ambarlı 2006).

Density at carrying capacity (K) is assumed to be 36 bears/100 km² so K is 288 within 800 km². Since this estimate is not certain, a standard deviation of 0.20 is assumed for K. In Croatia, the population size of bears is about half that of the carrying capacity (D. Huber, pers.comm.). This ratio is not clear for Scandinavia but there is no evidence that that population has reached its carrying capacity. Since our hypothetical population size is an estimate that is constructed by real field census values of years 2001, 2002 and 2004, it is highly probable that these assumptions reflect more or less the reality. Hence, the study population is set at an initial value of 144, at 50% of its carrying capacity (i.e. 288).

2.2.8. Initial Abundances

Initial abundances for each stage are identical to stable age distribution which is calculated by the software itself. Stable age distribution is such a distribution of the individuals into the age classes that after it has reached, the proportion of individuals in each age class remains same in the following years (if the environment is stable also but which is not a common case) (Akçakaya 2002). Initial abundances for all scenarios (except the alternative one) are as in Table 2.4, and for the alternative model in Table 2.5.

Table 2.4 Initial abundances for all scenarios

	CF	YF	S1F	S2F	S3F	AF
Initial Abundance	14	10	8	7	6	32
	CM	YM	S1M	S2M	S3M	AM
Initial Abundance	14	10	8	7	5	23

Table 2.5 Initial abundances for alternative model scenario

	CF	YF	S1F	S2F	S3F	AF
Initial Abundance	15	11	9	7	6	34
	CM	YM	S1M	S2M	S3M	AM
Initial Abundance	15	11	9	6	5	16

2.2.9. Stochasticity

Demographic and environmental stochasticities are taken into consideration in the model and sampling error for population size is taken as 0.15.

2.2.10. Catastrophes

There is no significant catastrophe which affects brown bears.

2.2.11. Dispersal and Correlation

There is no dispersal or correlation functions since only one population is modelled.

2.2.12. Population Management

The “Population management” option is used for both setting poaching values and harvest rates. Two separate poaching activities are assumed to be present simultaneously in the baseline non-harvesting model (“Scenario0 (illegal harvesting)”). Due to its illegal nature, poaching is difficult to document. However, various records (H. Ambarlı, pers.comm) indicate a significant number of individuals killed illegally in the study area. As a result of such activities, the following individuals are assumed to be removed from the population at every time step:

1) A total of 4 female individuals per year from all stages. Female cubs and yearlings of those females are removed as well because when a mother is killed then it is highly probable that her young will also die soon.
2) A total of 3 male individuals per year from all stages except for adults. Most young males get killed after entering into conflict with people. However, older males rarely approach settlements. Similarly, male cubs and yearlings are removed since when a mother dies her young regardless of their sex will also die soon.

There are also 2 simultaneous harvest activities for "Scenario1 (per year)" which are:

1) 2 males from Subad3 stage and 2 males from Adult stage per year.
2) 1 female from Adult stage per year because of misjudgement of her sex by the hunter. This is not uncommon since sexing of bears is not easy, especially in the low visibility conditions common during hunting.

For "Scenario2 (per year with misjudgement)" the following actions are present:

1) 2 males from Subad3 stage plus 1 male from Adult stage per year.
2) 2 females from Adult stage per year because of misjudgement of her sex by the hunter.

“Scenario3 (per 2 years)” assumes the removal of:

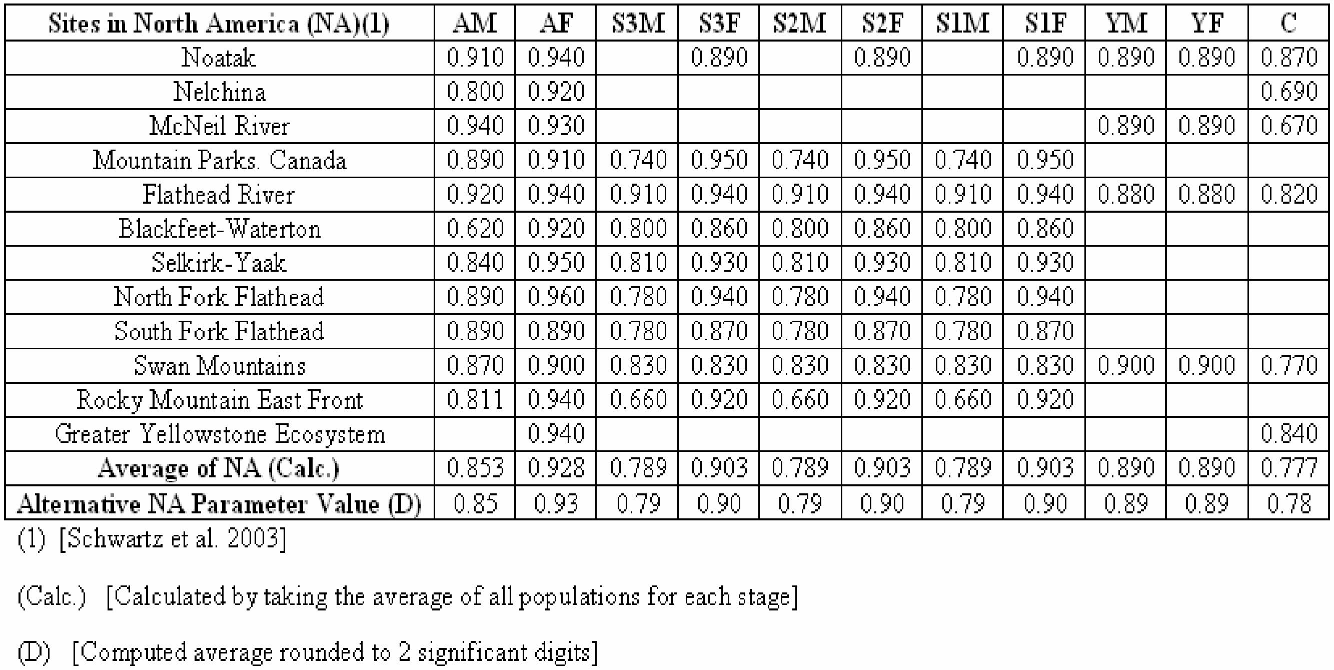
1) 2 males from Subad3 stage plus 2 males from Adult stage every 2 years.

2) 1 female from Adult stage every 2 years because of misjudgement of her sex by the hunter.

2.3. Data Gathering

Long-term detailed ecological research on Turkish bears do not exist (Can and Togan 2004, Ambarlı and Bilgin 2008). Therefore, input for the model was mostly based on bear life history data reported for elsewhere in Europe or N. America. The data sources used are from literature searches and personal communication with bear biology experts Dr. Djuro Huber (Croatia) and Dr. Jon Swenson (Norway). Below one can find the details of references and calculations of the survival rate parameters.

Table 2.6 North American survival rate parameter calculations with references



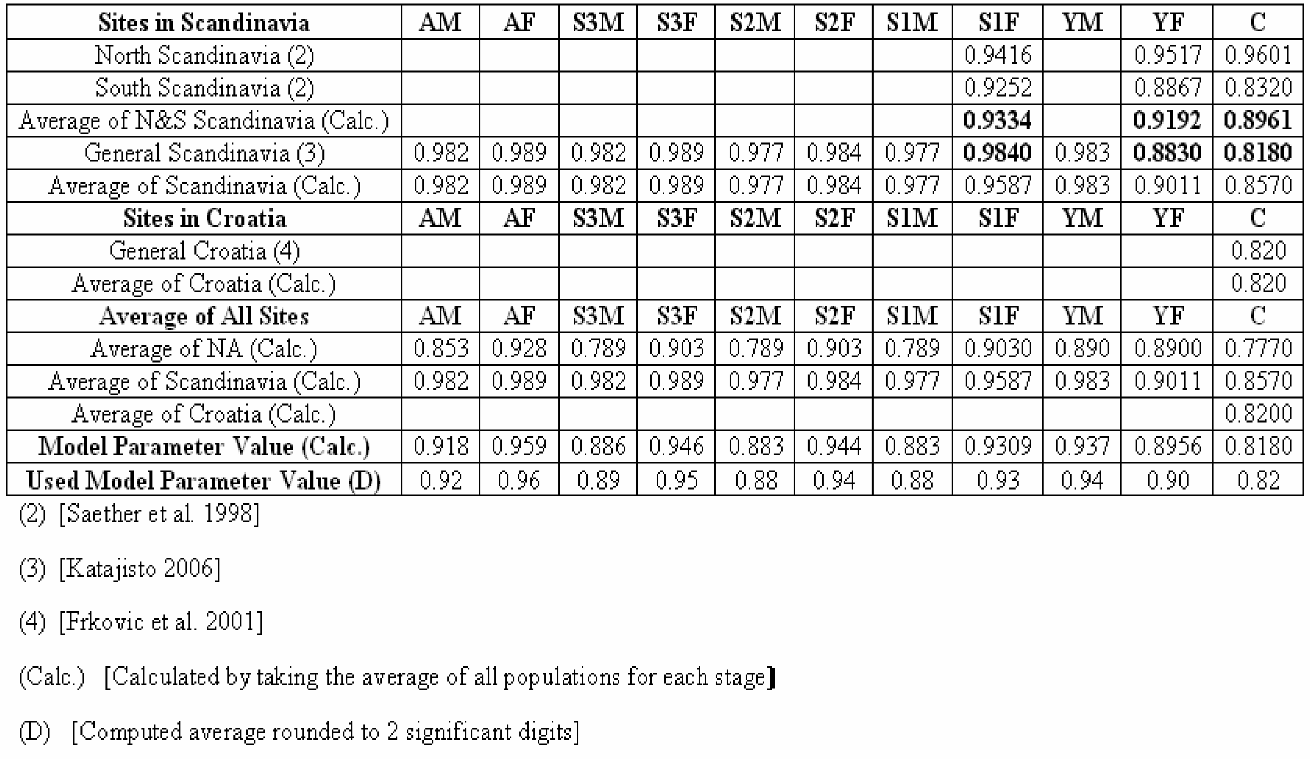
Sites in North America (NA)(1)	AM	AF	S3M	S3F	S2M	S2F	S1M	S1F	YM	YF	C
Noatak	0.910	0.940		0.890		0.890		0.890	0.890	0.890	0.870
Nelchina	0.800	0.920									0.690
McNeil River	0.940	0.930							0.890	0.890	0.670
Mountain Parks. Canada	0.890	0.910	0.740	0.950	0.740	0.950	0.740	0.950			
Flathead River	0.920	0.940	0.910	0.940	0.910	0.940	0.910	0.940	0.880	0.880	0.820
Blackfeet-Waterton	0.620	0.920	0.800	0.860	0.800	0.860	0.800	0.860			
Selkirk-Yaak	0.840	0.950	0.810	0.930	0.810	0.930	0.810	0.930			
North Fork Flathead	0.890	0.960	0.780	0.940	0.780	0.940	0.780	0.940			
South Fork Flathead	0.890	0.890	0.780	0.870	0.780	0.870	0.780	0.870			
Swan Mountains	0.870	0.900	0.830	0.830	0.830	0.830	0.830	0.830	0.900	0.900	0.770
Rocky Mountain East Front	0.811	0.940	0.660	0.920	0.660	0.920	0.660	0.920			
Greater Yellowstone Ecosystem		0.940									0.840
Average of NA (Calc.)	0.853	0.928	0.789	0.903	0.789	0.903	0.789	0.903	0.890	0.890	0.777
Alternative NA Parameter Value (D)	0.85	0.93	0.79	0.90	0.79	0.90	0.79	0.90	0.89	0.89	0.78

(1) [Schwartz et al. 2003]

(Calc.) [Calculated by taking the average of all populations for each stage]

(D) [Computed average rounded to 2 significant digits]

Table 2.7 Scandinavian, Croatian and model survival rate parameter calculations with references



Sites in Scandinavia	**AM**	**AF**	**S3M**	**S3F**	**S2M**	**S2F**	**S1M**	**S1F**	**YM**	**YF**	**C**
North Scandinavia (2)								0.9416		0.9517	0.9601
South Scandinavia (2)								0.9252		0.8867	0.8320
Average of N&S Scandinavia (Calc.)								**0.9334**		**0.9192**	**0.8961**
General Scandinavia (3)	0.982	0.989	0.982	0.989	0.977	0.984	0.977	**0.9840**	0.983	**0.8830**	**0.8180**
Average of Scandinavia (Calc.)	0.982	0.989	0.982	0.989	0.977	0.984	0.977	0.9587	0.983	0.9011	0.8570
Sites in Croatia	**AM**	**AF**	**S3M**	**S3F**	**S2M**	**S2F**	**S1M**	**S1F**	**YM**	**YF**	**C**
General Croatia (4)											0.820
Average of Croatia (Calc.)											0.820
Average of All Sites	**AM**	**AF**	**S3M**	**S3F**	**S2M**	**S2F**	**S1M**	**S1F**	**YM**	**YF**	**C**
Average of NA (Calc.)	0.853	0.928	0.789	0.903	0.789	0.903	0.789	0.9030	0.890	0.8900	0.7770
Average of Scandinavia (Calc.)	0.982	0.989	0.982	0.989	0.977	0.984	0.977	0.9587	0.983	0.9011	0.8570
Average of Croatia (Calc.)											0.8200
Model Parameter Value (Calc.)	0.918	0.959	0.886	0.946	0.883	0.944	0.883	0.9309	0.937	0.8956	0.8180
Used Model Parameter Value (D)	0.92	0.96	0.89	0.95	0.88	0.94	0.88	0.93	0.94	0.90	0.82

(2) [Saether et al. 1998]

(3) [Katajisto 2006]

(4) [Frkovic et al. 2001]

(Calc.) [Calculated by taking the average of all populations for each stage]

(D) [Computed average rounded to 2 significant digits]

Table 2.8 Fecundity rate parameter calculations with references

	Litter Size	Successful Breeding Interval	Whole Maturation age of F	Whole Maturation age of M
Average Scandinavia (5)	2.35	2.50	5.3	5.3
Croatia (pc. DH)	2.39	2.00	4	4
Total Average	2.37	2.25	4.65	4.65

(5) [Swenson et al. 2001]
(pc. DH) [Personal communication with Dr. Djuro Huber]

Population density parameters were recalculated after Ambarlı (2006) where density values ranged between 10.9 – 26.9 bears per 100 km². These values were averaged to a conservative estimate of 18 bears per 100 km². A more precise maximum local density of 25 adult bears was reported for Özgüven Valley. The assumption that 25 adults / 100 km² means 25 independent bears / 100 km², so that there are 25 individuals of age classes Subad2, Subad3 and Adult. This assumption implies that we only need to calculate the number of cubs, yearlings and subadults younger than 3. Even though sex ratio at birth is 1:1, since female survival is higher than that of males for Subad2, Subad3 and Adult stages, 14 of the 25 bears are assumed to be female. Even if 12 of them are assumed to be adult females and the other 2 individuals belonging to stages Subad3 or Subad2, there will be 12 * 0.90 * 1 / 2.25 * 2.37 = 11.376 ~ 11.4 young which are in Cub or Yearling or Subad1 stages. So the total number of bears is 25 + 11.4 = 36.4 which can be rounded off to 36. 12 is the number of alive female adults, 12 * 0.90 is the number of female adults potentially giving birth, 12 * 0.90 * 1 / 2.25 is the number of actual mother female adults and 12 * 0.90 * 1 /2.25 * 2.37 is the number of actual live young.

The general parameter list, their values and explanations as to how these values were obtained are given in Table 2.9 and Table 2.10.

Table 2.9 Other parameters

Parameter	Value	Unit	Explanation
Mean Litter Size	**2.37**	**cubs**	Average of Scandinavian and Croatian brown bears
Breeding Interval	**2.25**	**years**	Average of Scandinavian and Croatian brown bears
% productive adult	**90%**		ASSUMPTION
% productive Subad3 female	**35%**		ASSUMPTION by considering the reproductive maturation age
% productive Subad3 male	**0%**		ASSUMPTION that no adult male allow a young to breed in this age class
Male : Female at birth	**1 : 1**		ASSUMPTION
Study Area	**800**	**km2**	Area is identical to Ambarlı (2006)
Density	**18**	**per 100 km2**	ASSUMPTION by using the information in Ambarlı (2006)
Initial population	**144**		18 * 8 = 144
Density at carrying capacity	**36**	**per 100 km2**	ASSUMPTION by using the information in Ambarlı (2006)
Carrying Capacity K	**288**		36 * 8 = 288

Table 2.10 Survival and fecundity rate parameters

Parameter	Value	Explanation
Survival Adult M	**0.92**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.85)
Survival Adult F	**0.96**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.93)
Survival Subad3 M	**0.89**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.79)
Survival Subad3 F	**0.95**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.90)
Survival Subad2 M	**0.88**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.79)
Survival Subad2 F	**0.94**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.90)
Survival Subad1 M	**0.88**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.79)
Survival Subad1 F	**0.93**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.90)
Survival Yearling M	**0.94**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.89)
Survival Yearling F	**0.90**	Average of Scandinavian and North American brown bears (Alternative only NA = 0.89)
Survival Cubs	**0.82**	Average of Scandinavian, Croatian and North American brown bears (Alternative only NA = 0.78)
Fecundity ADULT	**0.45504**	[1 / 2.25] * 2.37 * 0.90 * 0.5 * 0.96 = 0.45504
Fecundity SUBAD3	**0.17512**	[1 / 2.25] * 2.37 * 0.35 * 0.5 * 0.95 = 0.17512

2.4. Minimum Viable Population (MVP)

One can define the minimum viable population (MVP) size as the smallest size required for a population to have a predetermined probability of persistence for a given length of time (Shaffer 1981, Reed et al. 2003). But as Wilhere (2008) states there is not a general rule for determining the MVP value all over the Earth, which results in different value assumptions in different studies such as Brook et al. (2006) and Howells and Edwards-Jones (1997). So one can say a population is viable if a 90% probability of persistence over 100 years is achieved (Brook et al. 2006) or it is viable when it has a probability 95% or higher survival during a 50 year period (Howells and Edwards-Jones 1997). As a result, in this study, it is decided to refer to a population as viable when it has at least 95% probability of surviving in a 50 year period.

2.5. Trophy Hunting and Related Scenarios

Trophy hunting simply means hunting animals for the trophy values, e.g. horns, pelt, teeth. This hunting activity of course must have a limit and this limit must be determined following rigorous scientific investigations. For many reasons, the limit should determine the safe survival of the species in the following years. In this study, the probability of extinction value of Scenario0 is considered as “no extinction” case.

Figure 2.3 Hunted brown bear in Kastamonu in 2007 after the legalization of trophy hunting

In the next table hunted brown bear quantities in the scenarios are given. Age stages of hunted individuals were written in part 2.2.12.

Table 2.11 Number and sex of hunted individuals in scenarios

	Illegal Killing		Legal Killing			
	Per year		Per year		Every 2 yeras	
	M	F	M	F	M	F
Scenario0	3	4	-	-	-	-
Scenario1	3	4	4	1	-	-
Scenario2	3	4	3	2	-	-
Scenario3	3	4	-	-	4	1

CHAPTER 3

RESULTS

3.1. The Future of the Population under Different Scenarios

Trajectory summary result of the simulations shows the average abundance with one standard deviation above and below as well as minimum and maximum values reached during a 50 year long simulation (Akçakaya 2002). Figure 3.1 shows the trajectory summary of the Yusufeli population under the baseline scenario (Scenario0).

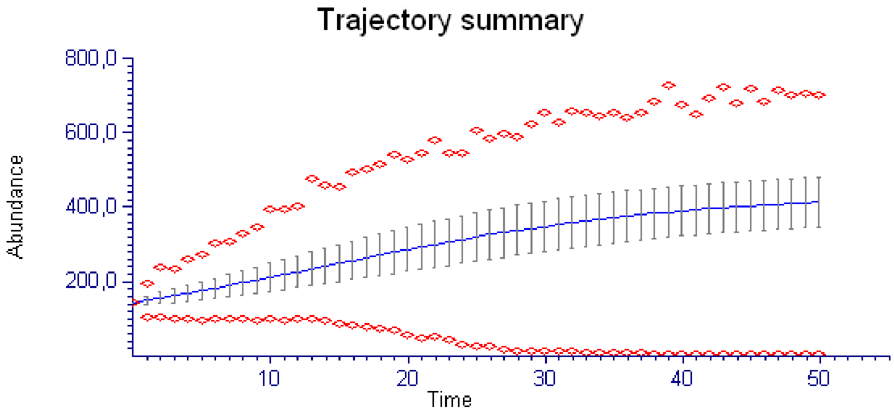


Figure 3.1 Trajectory Summary Graph for Scenario0

3.1.1. Extinction Risks

There are 2 kinds of extinction risks provided as a result under RAMAS Metapop. One is the interval extinction risk and it is defined as the probability that the (meta)population abundance will fall below a range of abundances at least once during the next duration time steps (Akçakaya 2002). The other is the terminal extinction risk and it is the probability that the (meta)population abundance will end up below a range of abundances at the end of duration time steps (Akçakaya 2002). Here, only interval extinction is used since it gives the chance to investigate all time duration step by step.

Extinction risk graphs show how often (Y axis) the abundance of the population fall below a threshold value (X axis). When extinction risk is bigger than zero (i.e. at least 1 run in 10000 runs population goes extinct) this is written on the upper left corner of the graph. The expected minimum abundance is presented at the upper right corner of the graph and it is determined by averaging the smallest population sizes observed in each of the 10000 iterations (McCarthy and Thompson 2001, Akçakaya 2002). If P (X) is the probability of decreasing to or below X individuals for all (integer) X in the interval [0,200], then in Figures 3.6 to 3.8, points refer (0, P (0)), (10, P (10)) (20, P (20)) and so on until reaching (200, P (200)).

The baseline scenario, namely Scenario0, gives an extinction probability of 0% for the study population any time in 50 years period (Figure 3.2).

Therefore, the model predicts no extinction at all under baseline conditions with no hunting but existent poaching.

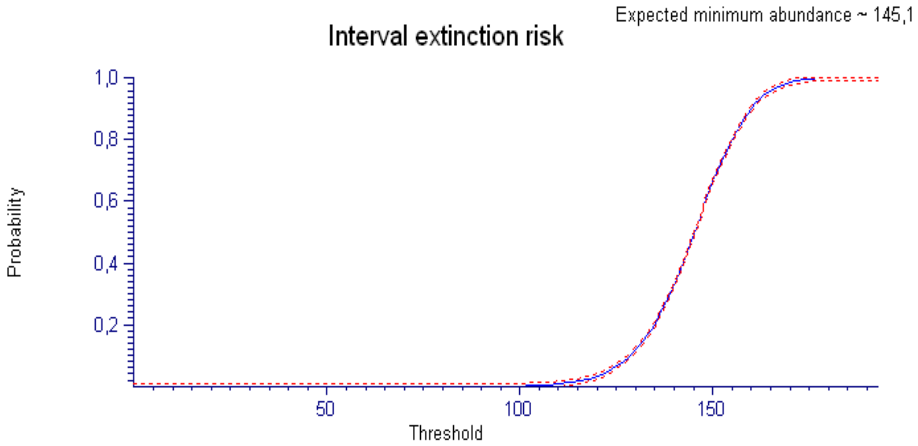


Figure 3.2 Interval Extinction Risk of Scenario0

Figure 3.3 show that an annual harvest according to Scenario1 causes an extinction probability of 15.3% for the study population any time during the next 50 years (i.e. the population has gone extinct in 1530 runs out of 10000 and the expected minimum abundance is nearly 114 individuals). The impact of legal hunting of 4 males and one female significantly raises the extinction risk.

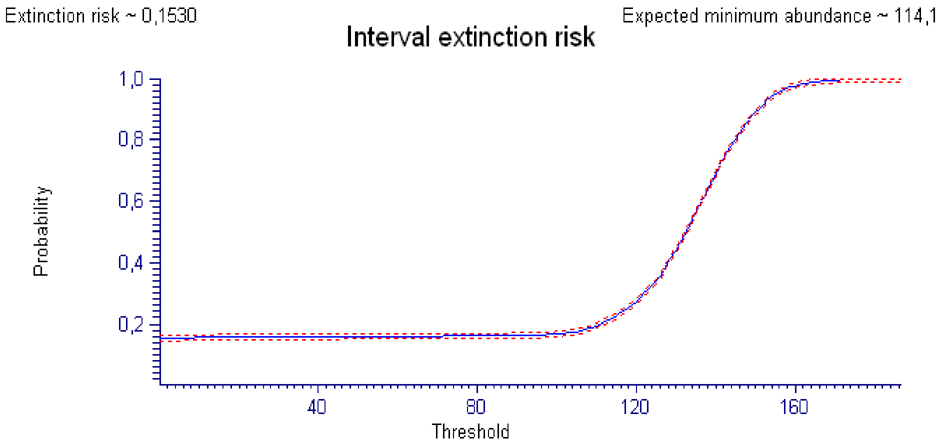


Figure 3.3 Interval Extinction Risk of Scenario1

Whereas in Scenario2, misjudgement of the sex of animals (leading to killing of an additional female in place of a male) increases this extinction probability to 26.07% within the same time context.

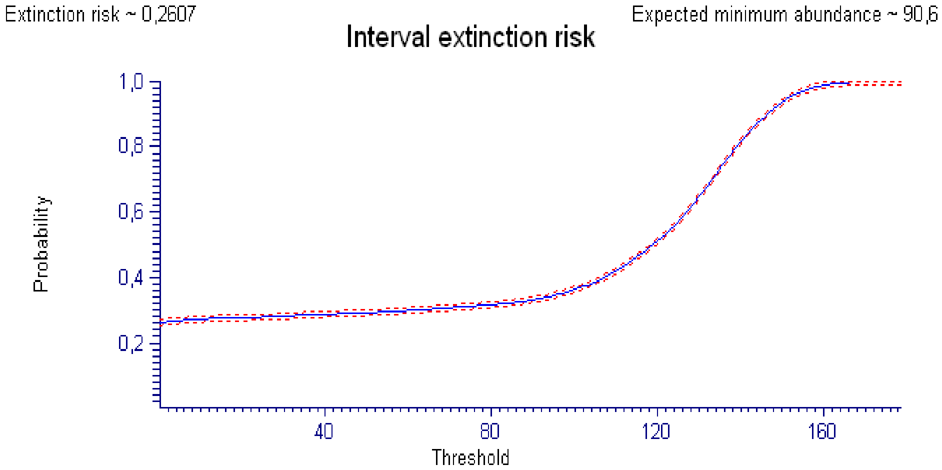


Figure 3.4 Interval Extinction Risk of Scenario2

Scenario3 which is the case of trophy harvest per 2 years gives a much smaller extinction probability of 0.1% at any time during a 50 year long period.

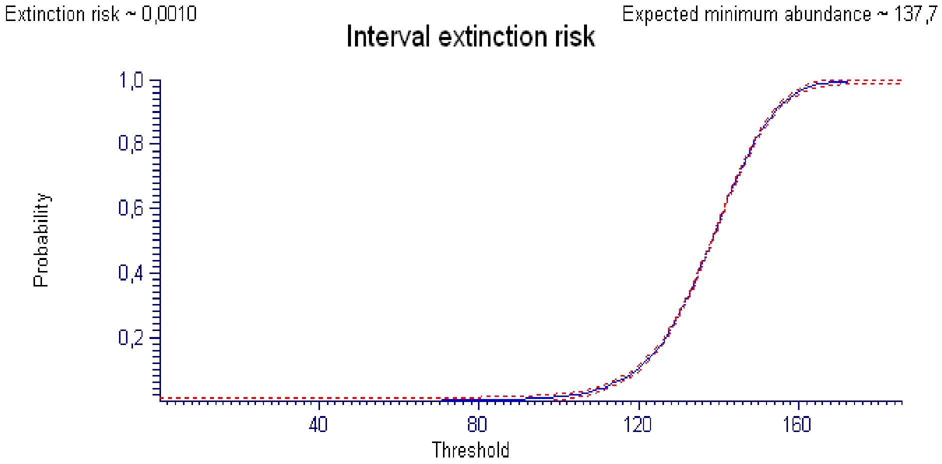


Figure 3.5 Interval Extinction Risk of Scenario3

A comparison of all four scenarios is shown in Figure 3.6. There is a clear distinction between low or no extinction risk scenarios (0 and 3) and higher extinction risk scenarios (1 and 2). The former group of scenarios almost never falls below 100 individuals at any time while the same probability ranges between 15 to 35 % for the latter scenarios.

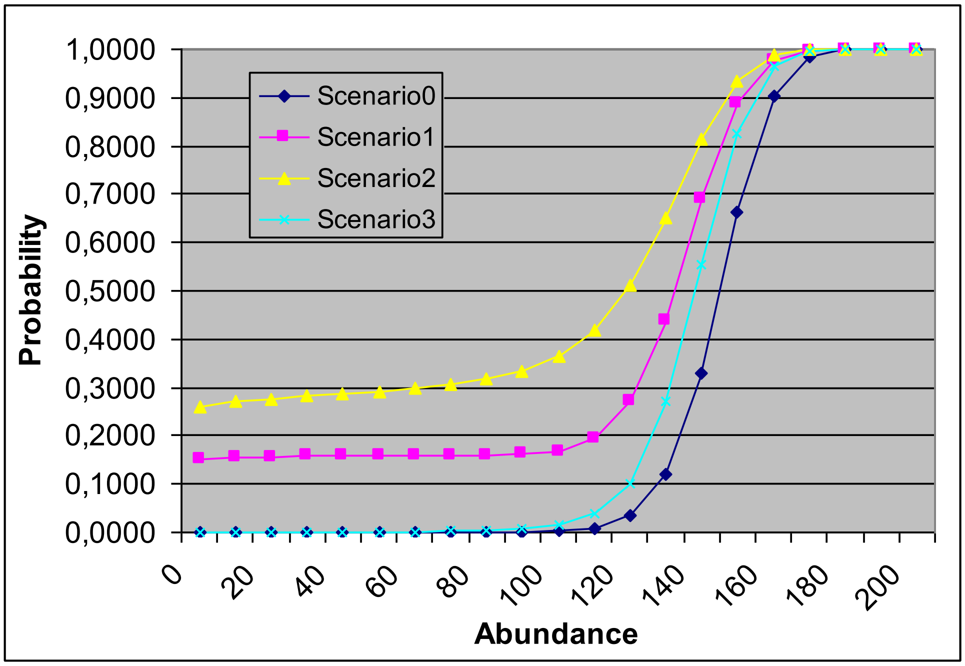


Figure 3.6 Graph of Interval Extinction Risks for all Scenarios

3.1.2. Viability of Populations

As stated in part 2.4, a population is accepted to be viable if its extinction risk is smaller than 5% in 50 years. Therefore the initial population abundance of 144 individuals is tested for viability under each scenario. A population size of 144 is viable in the case of Scenario0 whereas for Scenario1 the initial population abundance of 144 individuals is not viable and further implies that this figure is smaller than MVP size. Similarly, an abundance of 144 is not viable for Scenario2. Here also 144 is smaller than MVP size when the population suffers the effects of Scenario2. Lastly in the case of Scenario3 the initial abundance of 144 is once more viable.

3.2. Result of the Alternative Model for Scenario0

Alternative Scenario0 is a modified baseline scenario that is constructed with using only the North American survival rates. In such a case extinction probability is 1.9% at any time in 50 years period. This probability value is nearly equal to the probability of decreasing to or below 116 individuals in original Scenario0 (precisely the probability of decreasing to or below 116 individuals is 0.0206). As stated earlier, there is a 0% extinction probability in the original Scenario0.

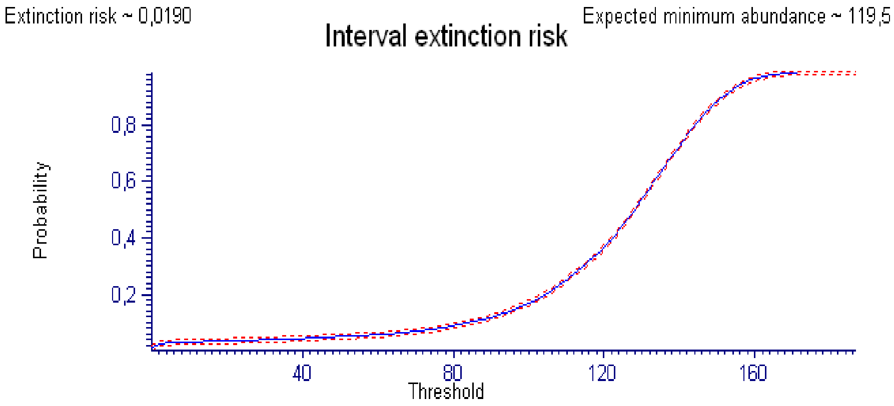


Figure 3.7 Interval Extinction Risk of Alternative Scenario0

A comparison of original and alternative baseline scenarios is provided in Figure 3.8. It is clearly obvious here that North American survival values lead to a slightly higher probability of extinction for the study population.

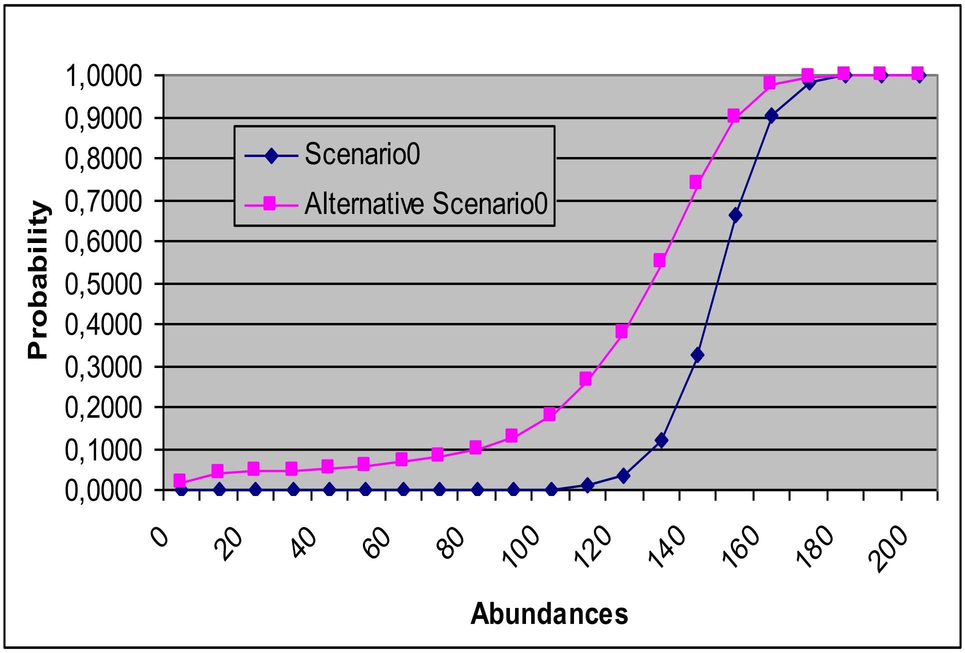


Figure 3.8 Graph of Interval Extinction Risks for Original and Alternative Scenario0

3.3. Sensitivity Analysis

Sensitivity analysis is a procedure used to find out which parameters are the most crucial ones for a model. Namely it shows which parameters are most influential in determining the model outcome. This analysis basically can be performed by increasing and decreasing all parameters for a certain percent for each and run the model such that only one parameter value is changed at a time. So one gets results twice the number of parameters - one set for increased ones and another for decreased ones. Then comparing a suitable result of the original model with those 2 sets of results and investigating the differences within and between parameters concludes the analysis. The compared result must be capable of showing a clear picture of the model outcome.

While doing a sensitivity analysis of the model, each parameter was increased and then decreased in turn by 10% and interval extinction risk results are used for comparing precisely the probability of decreasing to and below 100 individuals. Table 3.1 provides the outcome of sensitivity analysis with above formulation. There N means initial population size, K means carrying capacity, Rmax means maximum growth rate, Prob.of < 100 in original M means probability of decreasing to or below 100 individuals in original model.

Table 3.1 Sensitivity Analysis Result

	Normal Parameter Values	+ % 10	Probability of < 100 in increased case	- % 10	Probability of < 100 in decreased case
Survival AM	0.920	0.999	0.0190	0.828	0.0031
Survival AF	0.960	0.999	0.0004	0.864	0.0494
Survival S3M	0.890	0.979	0.0031	0.801	0.0016
Survival S3F	0.950	0.999	0.0027	0.855	0.0023
Survival S2M	0.880	0.968	0.0028	0.792	0.0018
Survival S2F	0.940	0.999	0.0014	0.846	0.0032
Survival S1M	0.880	0.968	0.0026	0.792	0.0006
Survival S1F	0.930	0.999	0.0008	0.837	0.0026
Survival YM	0.940	0.999	0.0027	0.846	0.0010
Survival YF	0.900	0.990	0.0011	0.810	0.0024
Survival C	0.820	0.902	0.0007	0.738	0.0036
Fecundity A	0.45504	0.500544	0.0011	0.409536	0.0020
Fecundity S3	0.17512	0.192632	0.0030	0.157608	0.0027
N	144	158	0.0003	130	0.0166
K	288	317	0.0006	259	0.0043
Rmax	1.1251	1.2376	< 0.0000	1.0126	0.9999
Prob. of < 100 in original M	0.0021				

CHAPTER 4

DISCUSSION

4.1. Implications of Sensitivity Analysis

An immediate implication of the sensitivity analysis is the need for rigorous field investigations about the actual growth rate of the study population. Since it is the most crucial parameter that affects the outcome it is worth giving all the effort, money or time to this path. Secondly, although it seems that maximum growth rate is individually important, its components are nothing but survival and fecundity rates. Therefore, rigorous research about these vital rates is the best choice if this model should reflect the reality as much as possible. Among those vital rates, female survival rate deserves even more special emphasis since it is also very important for the model. Thirdly, long term and reliable monitoring in the form of regular censuses must be done for further refinement of the model. Last but not the least, even though most times it is not easy to get precise information about the carrying capacity it is worth to try to further test the validity of related assumptions.

4.2. Discussion of the Results

The success of a PVA is largely dependent on the use of appropriate (that is, as close to actual rates as possible) parameter values for the model. This is not easy to prove and sometimes impossible to maintain. Nevertheless, through use of different scenarios one can at least investigate options and compare different lines of action.

Just like the suitability of the statistic coefficient of variation (CV) in comparisons in statistics, scenarios are suitable components of a PVA study for comparing the effects of different management actions. Without a very reliable data set it is highly improbable to get a true value for exact future abundances or numbers, but through a comparison of results of scenarios we can understand which ones are more conservation-oriented and which are destructive.

4.2.1. Assessment of Parameter Values

Since demographic studies on Turkish bears are missing, the values for model parameters were largely taken directly or adapted from those of bear populations studied in the Balkans, Scandinavia, as well in North America. Priority and higher weighing was given to data pertaining to European bears since the study population most likely resembled European populations in terms of vital parameters.

North American grizzly bear populations are considered to have a slightly different ecology than European and Middle Eastern brown bear populations, with higher consumption of animal prey, including concentrated supplies of salmon; they are also larger, slower maturing and perhaps more of a K-strategist. Therefore, whenever European data was sufficient they were used alone but in many instances North American data had to be included in the computation since European data was not extensive. In such cases, averages for both continents were taken.

Despite every attention was given to justify the use of selected values, there is always a possibility that the actual situation in Turkey is different than assumed. Although rather unlikely to be true, the model was also run using alternative survival parameters more similar to the North America situation. The outcomes of these alternative runs for Scenario1 and Scenario2 were extinction within 50 years, and for Scenario3 there existed a 76% probability of extinction. Therefore, it is absolutely important to know the exact parameter values from the study area as much as possible. Moreover, such research needs to be carried out soon because after a 10 years long interval trophy hunting of bears has started again and may continue in the future.

4.2.2. Comparison of Scenarios

The model outcomes (in the form of results of several scenarios) show that the bear population under study, faces a low to moderate risk of extinction within the relatively short period of fifty years. Assuming that the parameter values used in the model are not significantly different than actual values, the baseline model with no legal hunting and a moderate level of losses due to illegal poaching (i.e.Scenario0) predicts a viable population. However, any additional mortality - legal or illegal – causes a significant increase in the risk of extinction and even results in an nonviable population.

Both Scenario1 and Scenario2, involve trophy hunting of five adult or subadult animals every year in addition to 7 poached individuals. The difference between these two scenarios is that one and two of the legally shot bears are female for the former and the latter scenario, respectively. Even this small detail on the sex of the killed bears causes a significant change in the probable risks. Scenario2 where more females are shot has up to nearly twice the level of risk of extinction compared to Scenario1. This is expected since (as the productive sex in most populations) females are more important, but still the observed difference between the outcomes is surprisingly obvious.

Scenario3 differs from others in the fact that trophy hunting does not occur every year but only every two years. Hunting every 2 years seems to be crucial for safe survival of the species if trophy hunting continues for a long period. Even giving one year for recovery plays a vital role in reducing the extinction risk from levels of Scenario1 to almost levels of Scenario0, the baseline situation with no trophy hunting. Overall, two of the scenarios (0 and 3) are viable in the sense that they have less than 0.05 probability of extinction over 50 years.

4.2.3. Consequences of Possible Allee Effect

Allee effects occur when typical negative feedback population mechanisms are replaced by positive feedback mechanisms below a certain population threshold and lead the population to extinction (Courchamp et al. 1999). This is especially witnessed in populations of higher organisms, such as large vertebrates, where complex social behaviour is observed. A reduced probability of finding mates or breakdown of social rules may easily cause extinction in very low density populations of bears and other large mammals.

Therefore, extinction does not necessarily require reaching zero population size but may effectively be reached when, say the population density reaches a low value; no matter how the conditions improve, the population ends up extinct once this threshold is passed. In this study the population was considered extinct only when no individuals were left alive. However, even if this threshold was set to 20 (i.e. the population was considered extinct when it is reduced to 20 individuals) the associated interval extinction risks did not increase more than 6% at most. Therefore, Allee effects can probably be safely assumed to be of no significant impact in this case.

4.2.4. Effects of Hunting

There are two different modes of hunting in the study area. Poaching involves illegal ongoing killing of "problem" bears mostly by the locals. The magnitude of this type of hunting is not clear but by all accounts it seems to be considerable. Therefore, the annual value of 7 bears killed used in the model seems to be a representative estimate. The other type of hunting is legal and aims to bring high trophies, meaning killing of largest bears if possible. This activity takes place intermittently and the last such episode of hunting was in 2007.

While Scenario0 with no trophy hunting is viable in the sense that they have less than 0.05 probability of extinction over 50 years, Scenario1 and Scenarios2 (limited trophy hunting is allowed every year) are not viable as they lead the study population to extinction in the simulations. This result clearly shows the impact of hunting towards the population. In a similar way, Scenario3 where trophy hunting occurs only every two years is viable again, being intermediate between baseline situation and the two unviable scenarios.

If we look the results of scenarios it is obvious that misjudgement of the sex of bears gives a considerable harm to the population. Even an expert can find it hard to distinguish between an adult male and an adult female without her young. Therefore in the case of trophy hunting such misjudgement is highly probable to occur and will increase the extinction risk like in Scenario2.

To sum up if a hunting activity takes place it must be at least 2 years apart and also hunters must be accompanied by a bear expert for the correct identification of the sex of the animal.

CHAPTER 5

CONCLUSION

5.1. Management Implications and Suggestions

It has been shown here that hunting of any type impacts the bear population in a strong way and when both occur simultaneously every year they lead to the extinction of the population in the long run. The avoiding of illegal hunting and a close supervision of trophy hunting is crucial in the management of this population of bears.

The simulations have shown that allowing trophy hunting every year is detrimental to the population. It is recommended that such trophy hunting should not be more often than every two years. In addition, the sex of the shot bears also affect the viability of the population and mistaken killing of female bears should be avoided at all costs. If poaching can be reduced to levels much lower than current levels, then limited annual trophy hunting can be resumed, provide there is a justification for such an intervention.

If the density of bears does not cause a problem there is not any reasonable explanation for allowing legal hunting. Because male biased hunting can cause many negative effects to the population dynamics (Wielgus and Bunnell 2000, Swenson et al. 2001, Katajisto 2006, Milner et al. 2007). It is even worse to hunt females by misjudgement or intentionally since they are the keystone components for the reproduction activity of population. Therefore, the Turkish Ministry of Environment and Forestry should define what a “problem bear” is; then prove it with a strong data set and carry out further monitoring of the population and detailed research to generate vital rates data in the area. Only then legal hunting activity can be performed with scientifically determined quotas and periods.

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