The Yellow-shouldered Amazon

Perspectives

Thesis

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Preface

A viability analysis can be conducted on any threatened species, so why did I chose the Yellow-shouldered Amazon and specifically the population inhabiting Bonaire? In my third year at Inholland university I went to Bonaire for an internship at the Washington Slagbaai National Park (WSNP). Sadly there were no opportunities to work with the parrots at the time, but I did got to witness them on many occasions. I was confronted with the situation of the parrots on my first day in the park. A parrot was kept at the lodge where I was accommodated, to recover from its former life as a pet. The wings were almost fully grown so it could be set free again soon.
And now after two years and from 7800 kilometers away I could finally do a study on this beautiful bird!

My first encounter with a Yellow-shouldered Amazon at WSNP

I would like to thank Jana Verboom-Vasiljev for her guidance during my internship at Alterra and for giving me the opportunity to learn more about population dynamics. I would also like to thank Rene Jochem who has helped me to acquire a basic understanding of the simulation program METAPHOR. Many thanks to Sam Williams for taking the time for an interview with Jana, Rene and me while he was on holiday in the Netherlands and also for sharing his thesis which described the results of his three year field study on the Yellow-shouldered Amazon. And finally I would like to thank Rozemarijn Sikkes, Angela van Beek and Dario Zambrano for their support.

Summary

There are 330 parrot species worldwide, of which a third is threatened with extinction. The Yellow-shouldered Amazon (*Amazona Barbadensis*) is a parrot species found in northern Venezuela and on the Caribbean islands Margarita, La Blanquilla and Bonaire. The total population size is estimated at 3.000-10.000 parrots, which has led the IUCN to classify its global condition as vulnerable. The population size on Bonaire is estimated at 800 parrots.

The goal of this study was to examine both the threats *A. Barbadensis* is facing on Bonaire and the opportunities to resolve them. Three methods were used during this process. First a literature study was conducted regarding the population dynamics of *A. Barbadensis* on Bonaire, resulting in a quantification of the different population parameters and environmental factors, affecting the parrot population. Secondly, a population dynamics simulation model was used to determine the sensitivity to changes in these environmental factors and population parameters. The model was finally used to analyze the impact of several scenarios on the population size over a period of 200 years.

The most important factor constraining the growth of the parrot population on Bonaire, is the limited number of nest sites in both trees and cliffs. Nest site limitation is inferred from the fact that only 21.5% of the population breeds annually. The low supply of tree cavities is caused by the exotic and invasive goats and donkeys who are responsible for the degraded state of the vegetation since their introduction in the 16^{th} century. An eradication program would allow the ecosystem to restore to its natural balance. *A. Barbadensis* would benefit by increased survival in all life stages due to a substantial increase in food resources, which will prevent the parrots from having to visit the hazardous urban areas, and by an increase in the number of nest sites. The scenario exploring the effects of this drastic measure reveals a population growth to several thousands of parrots.
It must be noted however that this scenario does not include any density dependant factors that would eventually limit the growth rate.

The population is most sensitive to changes in juvenile and adult survival, which corresponds with the r/K selection theory and another theoretical viability study regarding *A. Barbadensis*. Conservation initiatives should therefore focus on increasing their survival as it will be more beneficial to the persistence of the species than improving upon chick survival and female reproductivity.

The exact effects of climatic stochasticity on parrots are not well known. This study assumed the climate affected both survival in all life stages as well as reproduction. Changes in the impact of the climatic stochasticity showed a high sensitivity, which emphasizes the need for a better understanding of the impact the climate has on the survival and reproductive parameters of *A. Barbadensis*.

The parrot population on Bonaire can be considered as viable as the current conditions will not lead to extinction, nor will any of the other scenarios examined in this study. However, the reality might consist of a combination of these scenarios, affecting the parrot population more severely. It is therefore recommended, as a bare minimum conservational approach, to maintain the annual count of the population size in order to readily notice a decline in population size, enabling counter measures to be taken accordingly.

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Glossary

Burn in period: The period of time that is needed for a simulation model to stabilize from its initial value to an average, generated by the different parameters and factors that affect the variable.
CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora; an international agreement between governments to prevend the extinction of species caused by the trade.
Degraded vegetation: Vegetation that has lost its natural rich biodiversity caused by human activity.
Eradication: The elimination of all members of a species from a confined area.
Hatchability: Viable eggs at the end of incubation.
Interspecies competition: Competition between different species for resources.
Intraspecies competition: Competition between individuals of the same species for resources.
IUCN: The international union for the conservation of nature, a global environmental organization.
Poaching: An activitity where nestlings are collected in nature for the illegal pet trade.
Roost: A roost is a place where the parrots gather in the evening to spend the night.
Semi-arid climate: A climate where the annual rainfall averages between 250 and 500 mm .
Stochasticity: Fluctuations in biological and ecological processes, caused by variability and randomness.
Viability: The ability of an organism or population to persist independently.
Xerophytic vegetation: Vegetation that is adapted to a lack of water.

Introduction

This study is executed on behalf of the science institution Alterra, located in Wageningen, and represents the graduating part for the student Robin Sekeris who is majoring in Forest and Nature Management at Hogeschool Inholland.
Alterra comprises several research centres which together form the Environmental Science group. This study was carried out at the centre Landscape within the team Ecological Modelling and Monitoring which is led by Dr. Jana Verboom-Vasiljev. She has also been the supervisor of this project.

The Yellow-shouldered Amazon (*Amazona Barbadensis*) is a globally endangered parrot species, its state classified as vulnerable (IUCN 2011). *A. Barbadensis* is found in the northern mainland of Venezuela as well as its islands La Blanquilla and Margarita and on the island of Bonaire, which is part of the Netherlands Antilles. The total population is estimated at a range of between 2500 and 10000 parrots (IUCN 2008). This large uncertainty is caused by the lack of research studies on the mainland of Venezuela.

For conservation purposes it is important to know which factors are threatening the population and are constraining its growth. The most effective way to achieve this, but also the most expensive and time consuming, is a long lasting field study. Another possibility (which also works complementary to a field study) is a population viability analysis. This method uses a model to predict spatial and temporal changes in the size and composition of a population. The output can be displayed in a population size over time or in an extinction risk.
Population viability analysis can be used to determine critical life stages and critical environmental factors. Possible management strategies can also be assessed on their effectiveness.
Alterra has developed such a tool for population analysis, called METAPHOR. This program will be used to gain insight in the population dynamics of *A. Barbadensis* on Bonaire. Based on the results of METAPHOR, recommendations can be made regarding which management options will be most effective in strengthening the viability of the parrot population on Bonaire.

The main research question is defined as:
What are the main threats the Yellow-shouldered Amazon is facing on Bonaire and which management measures are most effective in increasing the viability of the population?
This main research question is divided into five sub questions:

- Which values can be assigned to the life history parameters of the Yellow-shouldered Amazon on Bonaire?
- What are the demographic values of the parrot population on Bonaire?

- Which environmental factors influence the parrots population dynamics and what are their corresponding parameter values?
- For which of the environmental factors is the Yellow-shouldered Amazon most sensitive?
- Which scenarios are possible on the long term (200 years) regarding the environmental factors and what kind of effect do they have on the viability of the parrot population?

Different methods were used to answer these questions. In order to create a model that generates realistic predictions, all the factors influencing the population have to be determined and quantified. These values have been gathered through the study of primary literature regarding several species of the genus Amazona. Dr. S. Williams, a local expert in the ecology of *A. Barbadensis*, has been approached and interviewed on several occasions. The gathered parameter estimations were integrated in the model in METAPHOR which was run subsequently to provide answers for questions about the sensitivity to parameter changes and the effectiveness of management options and the impact of other possible scenarios.

This research study is restricted to the population dynamics of the *A. Barbadensis* population on Bonaire. Environmental catastrophes are not included in the model as an event, but can be assessed by allowing a high standard deviation in survival rates.
Many parameter values are extracted from the thesis of Dr. S. Williams, who did a field study on the factors affecting the *A. Barbadensis* population on Bonaire. However, this field study lasted only three years which is a short period of time to provide reliable estimates, as there are fluctuations over time in the different factors.
Not all the information needed to include in the model was available for the parrot population on Bonaire, therefore some values were gathered from a field study on Margarita island, Venezuela.

The introduction is followed by the chapter Methods, which describes the design of the study. Next is the chapter backgrounds where a basic understanding will be established of the conservation problems the government of Bonaire is facing and what possible opportunities there are for increasing the viability of the population. This chapter is followed by two chapters that describe the results of the different sensitivity analyses and scenarios. The discussion provides an interpretation of the results and compares them with related literature. An advice on parrot conservation for Bonaire is given in the chapter Recommendations. The report ends with the Conclusions.

2 Methods

The Yellow-shouldered Amazon (*Amazona barbadensis*) is an endangered parrot species found in Venezuela and on the island of Bonaire, which is part of the Netherlands Antilles.
The aim of this research is to study the threats *A. Barbadensis* is facing on Bonaire and what measures can be taken that have most effect in preserving the population.
A population simulation model is used to analyze these topics.
The research is divided into four phases: Literature study, Analysis, Vision and Recommendations. This chapter lists every research question, divided between the phases and by what means these questions are answered.

2.1 Literature study

In order to create a realistic functioning model, the life history parameters of *A. Barbadensis* and all the factors influencing the parrot population have to be determined and quantified. The literature study provides answers to the first three research questions defined in the Plan of action. Each of these questions will be shortly discussed.

- **Which values can be assigned to the life history parameters of the Yellow-shouldered Amazon on Bonaire?**

Life history parameters are key characteristics of a species in a specific environment and a result of benefit-cost tradeoffs to maximize the fitness (number of surviving offspring). Examples are fecundity (number of offspring), age at sexual maturity and the duration of the different life stages. This question is answered by studying primary literature.

- **What are the demographic values of the parrot population on Bonaire?**

Demographic statistics define the size, structure and distribution of a population and also include birth- and death rates. These values are also gathered by examining primary literature.

- **Which environmental factors influence the parrots population dynamics and what are their corresponding parameter values?**

This is another question where the thesis of Dr. S.R. Williams (2009) is more than useful. There are also several studies available from the Venezuelan islands Margarita and La Blanquilla that provide useful information.

2.2 Analysis

The sensitivity of the population for different averages of - and fluctuations in environmental factors, demographic and life history parameters is analyzed with the simulation program METAPHOR. This is an individual-based population model that can simulate the population trend over time and space. The model monitors the population once every year, in which the individuals can reproduce, age and die. The results of METAPHOR are expressed in population sizes over time revealing increases and decreases. This method is preferred over expressing the effects of changes in parameters and factors in an extinction risk, because the extinction risk of *A. Barbadensis* on Bonaire is likely to be low (pers. comm. J. Verboom-Vasiljev, 2011)
The analysis phase addresses two research questions:

- **For which of the environmental factors is the Yellow-shouldered Amazon most sensitive?**

To answer this question several sensitivity analyses are carried out to measure the effect of changes in averages and standard deviations on the population over a timespan of 100 years into the future. Factors include poaching, number of nest sites and urban development. The effect of changes in survival rates and fecundity are also analyzed.

- **Which scenarios are possible on the long term (200 years) regarding the environmental factors and what kind of effect do they have on the viability of the parrot population?**

The future of the *A. Barbadensis* population depends on many factors. A few examples: Urban development is expanding and results in habitat loss; feral goats prevent rejuvenation of the vegetation and therefore limit the food supply and nest sites of *A. Barbadensis*; young chicks are illegally poached and sold for the parrot trade as a means of income for local inhabitants.
During the Vision phase several different scenarios are described (current situation, poaching, climate change, urban development and conservation,) and their effects over time will be examined by METAPHOR.

The results of the sensitivity analyses are analyzed statistically. The one-way ANOVA post hoc LSD test is used to test for significant differences between the medians of the different classes each parameter is divided in.

2.3 Vision

As a vision on the prospectives of *A. Barbadensis* on Bonaire, five scenarios are described.

Current scenario:
The current scenario is the baseline for which the other scenarios can be compared with. It includes all the current parameter values.

Poaching scenario:
Poaching does not only negatively affect chick survival, but also the number of available tree cavities due to the detrimental extraction method of cutting holes at nest height. The effect of a decline in tree cavities is explored in this scenario.

Climate change scenario:
The climate has direct and indirect effects on the population. Direct effects are climatic catastrophes which are not and will not be included in the model (Bonaire is not located in the hurricane zone). An indirect effect is the amount of precipitation affecting the state of the vegetation and thus the food resources of the parrots. Dry years are correlated with higher mortalities in all life cycles and wet years with higher survival and larger clutch sizes. A climate change resulting in more annual rainfall and a change in less annual rainfall will both be analyzed.

Urban development scenario:
Currently there are two scenarios developed by the government. They differ in the impact on Bonaires natural environment. The effects of both scenarios are translated in the number of lost nest sites. The scenarios of the government have a lifespan of 15 years. The number of nest sites lost is therefore repeated every 15 years to simulate continuous urban development for the next 200 years.

Conservation scenario:
The measures taken in this scenario include the eradication of the exotic and invasive mammals on Bonaire, the elimination of poaching, no further urban development and the laying-out of irrigated gardens with fruits grown for the parrots to forage on in drier years until the habitat is restored. The effects of each of these measures are also analyzed separately.

2.4 Recommendations

The different analyses result in a better understanding of the threats *A. Barbadensis* is facing on Bonaire. When the impact of the threats and of the counteracting measures is known, a list of recommendations can be made that aid in improving the viability of this endangered species.

3 Backgrounds

This chapter will provide the context that is needed to understand the population dynamics of the Yellow-shouldered Amazon (*Amazona Barbadensis*) on Bonaire and why population viability analysis is a useful method to explore the threats and opportunities for this species.

3.1 Population dynamics

Population dynamics is an important part of conservation biology. Before describing the contents of population dynamics, first the term 'population' has to be defined. A population is a specified number of individuals of the same species in a topographically or geographically confined environment, which can differ in scale from a local habitat type to the entire world (Soulé, 1987; Solomon, 1969). When a species consists of several spatially separated groups who interact with each other, they can be referred to as a metapopulation (Smith & Smith, 2009)

To understand the dynamics of a population, knowledge of the species' biology is required as well as any differences between the populations under study and other populations (Solomon, 1969).

Population dynamics studies the change of the number of individuals in a population and the biotic and abiotic factors that are causing these changes. Population dynamics is mainly about numbers. For example numbers about the size of the population, the rate of population decline/recovery, the sex ratio and the age structure (Solomon, 1969).

The size of a population changes by births, deaths and migrations and is summarized in the growth rate. These processes are stochastic which means they are of a probabilistic nature. There are three types of stochasticity: Demographic, environmental and catastrophic stochasticity (Soulé, 1987).

Demographic stochasticity is the uncertainty within the individuals that make up the population. Individuals differ genetically which is expressed in their reproductive abilities and survival skills.

Environmental stochasticity is the uncertainty in survival rates and fecundities brought about by factors from the environment. Examples are the weather, predation, competition and diseases.

Catastrophic stochasticity is basically an extreme form of environmental stochasticity, where a large proportion of the population dies (Soulé, 1987).

Demographic and environmental stochasticity are included in this study, whereas catastrophic uncertainty is not. Catastrophic events will eventually be implemented in the model, but not in the time period of this graduating study.

There are three different methods to study population dynamics. The first is the field study, where a population's characteristics are monitored in the species' natural environment. The problem with field studies is that there are always different possible explanations for the observations made, caused by confounding variables. To eliminate these variables the study can be carried out under artificial conditions in a laboratory, which is the second method. A drawback of this approach is the tendency to oversimplify the complexity of the situation in the field. This is also true for the third method, the theoretical study, which uses mathematics and models to answer questions regarding population dynamics (Solomon, 1969). This method is used in this study and is further described in the next paragraph.

3.2 Population viability analysis

Population viability analysis (PVA)is a theoretical method where species specific data and models are used to make predictions about the viability of a population over time, expressed in a risk of extinction or decline (Boyce, 1992). PVA is therefore an important utility used for the management of threatened species (Doak et. al., 1994).
When is a population viable? The answer is often summarized in a single number: The minimum viable population (MVP). But there is not one magic number: The MVP is unique for every situation. It depends on many factors like the species' biology, its endemicity (if, for example, the entire species is restricted to this one population) and the accepted level of risk of extinction (Soulé, 1987). A more concrete approach is to use the current size of the population as a baseline and use the model to determine its chance of persistence over time.

PVA can serve different purposes. With the aid of the model, the parameters that have most effect on the viability can be determined and it can also identify which stages in the species lifecycle are most sensitive to changes in these parameters. Furthermore, different management decisions can be assessed regarding their impact on the population size. A third use is the classification of a species in a degree of extinction risk by quantitive analysis, which is used by the IUCN in their Red list of threatened species. There are three categories for endangered species. A species is 'critically endangered' when the probability of extinction in the wild is larger than 50% within 10 years; 'endangered' when the probability of extinction in the wild is larger than 20% within 20 years and 'vulnerable' when the probability of extinction in the wild is at least 10% within 100 years (http://www.iucnredlist.org). Finally PVA can be used to assess the impact of human activities (Akcakaya et. al., 2009).

PVA has several advantages over other methods: The mechanics of the model and the assumptions are transparent and can easily be replicated, diverse types of information and uncertainties can be integrated and confounding variables present in the field can be taken apart. It can also uncover relationships between factors that were previously unknown.
Of course there are also several drawbacks: PVA can take a lot of time; it needs data that is often unavailable; it requires an expertise in modeling and population dynamics; and often many assumptions have to be made, which makes the value of the results questionable when they are presented with large confidence intervals (Akcakaya et. al., 2009).

The validity of the model depends on accurate estimations of all parameters and an accurate estimation of the species behaviour over time (Beissinger and Westphal, 1998)

3.3 Bonaire

The population viability analysis of *A. Barbadensis* is based upon the resident population inhabiting Bonaire.

Bonaire is an island in the Southern Caribbean sea and constitutes a special municipality of the Netherlands. Together with Saba and Sint Eustatius, these three islands represent the Caribbean Netherlands and are also known as the BES islands (http://www.gemeentebonaire.com).

Bonaire has a surface area of 288 km^2 and is located between 68° 11' en 69° 25' West and 12° 2' en 12° 19' North (Figure 3.1). Bonaire is about 39 km long and 5-11 km wide. The distance between Bonaire and the mainland of Venezuela is 80 km (http://www.bonairenet.com).

Figure 3.1 Map of Bonaire (http://www.planetware.com)

Currently Bonaire has a population of about 16.000 inhabitants living mainly in the two towns Rincon and Kralendijk. (http://www.banboneirubek.com) This number is expected to grow to 25.000 in 2025 (Lammens 2010).

The average annual temperature is 28˚C with small fluctuations (± 3˚C) between the seasons. The rainfall is irregular and local, on average 463 mm a year. About 51% of the annual rainfall falls during the rainy season in October, November and December.
There is a near constant trade wind on Bonaire from the north-east. Hurricanes are rare. On the north side is the Washington-Slagbaai National Park (WSNP) which is under management of the NGO Stichting Nationale Parken (STINAPA). The WSNP covers a fifth of the surface area of Bonaire. On the left side of Bonaire there is an uninhabited small (5 km) island called Klein Bonaire.

The vegetation on Bonaire is of a xerophytic nature due to the semi-arid climate and the localized and irregular rainfall. The tall flora is dominated by candle cactuses and thorny hardwood, but they rarely exceed 5 meters in length (Williams, 2009). The vegetation on Bonaire is in a degraded state, caused by historic tree felling and the introduction of feral goats and donkeys by the Spanish colonists in the 16^{th} century. These invasive mammals roam freely over the island and have prevented the vegetation from regenerating up until today (Freitas, et.al., 2005). Another factor causing further habitat degradation are the poachers who cut holes in trees for an easy access to the nestlings, which not only damages the tree but destroys the nesting habitat for cavity nesting birds (Williams, 2009).

Birdlife International classified the Caribbean Netherlands as important bird areas giving special attention to the Yellow-shouldered Amazon on Bonaire for its globally vulnerable state and because it is the only threatened bird on the BES islands (Brown, et. al. 2009).

3.4 The Psittacidae family

The order Psittaformes comprises two families, the Cockatoos and the Psittacidae. All birds in the order Psittaformes are parrots, but only the Psittacidae are considered as true parrots.

Parrots play an important role in tropical ecosystems as they disperse seeds and are able to digest the hard coats that surround the seeds (Galetti, 1993). Additionally, parrots form a prey for a wide variety of predators, from snakes to birds of prey (Williams, 2009; Sanz & Rodríguez-Ferraro, 2006).
There are 330 known species of parrots in the family Psittacidae of which one third is threatened to a certain degree of extinction (http://iucnredlist.org). This is more than in any other bird family (Bennett & Owens, 1997).

The threats parrots are faced with in the wild are numerous and more often than not have an anthropogenic origin. The two factors considered prevalent for the global decline of parrot populations are habitat loss and the capture of nestling parrots for the illegal pet trade (Juniper & Parr, 1998). The effects of exotic and invasive species are another important factor for the decline of many parrot species (Engeman, 2006; Blackburn et. al., 2004).

The parrots vulnerability is explained by the r/K selection theory which describes r and K selected species, where r stands for growth and K for carrying capacity. R selected species have a high growth rate, a short lifespan, minimal parental care and thrive well in instable environments. K selected species have a low growth rate, a longer lifespan, a population size at carrying capacity with fierce competition, extensive parental care and suited to stable environments (Gunderson, 1980). Parrots are K selected. Their clutch sizes are small, clutches are laid only once a year and both parents are involved in raising the young (Wright, et. al. 2001). As K selected species they are very sensitive to the instability of the environment caused by human activities.

All parrots are secondary cavity nesting birds, which means they are not capable of creating their nesting cavities like the primary cavity nesting birds. Parrots are therefore dependant on the availability of rock cavities and tree cavities arisen by decay or excavated by other bird species. The competition for these cavities is often fierce (Williams, 2009).
Because of their nesting requirements parrots prefer a tall and mature vegetation structure (Juniper & Parr, 1998). The vegetation is also their food resource as parrots are mainly frugivorous and can digest both the pulp and the seeds of the fruits (Silvius, 1995). Parrots also eat stems, flowers and leaves (Juniper and Parr, 1998).

3.5 Amazona Barbadensis

There are 86 genera within the Psittacidae family. The genus Amazona consists of 31 parrot species which are distributed through Central and South America. Their habitat preference is very diverse ranging from dry scrub to tropical rainforests (Juniper & Parr, 1998). 16 Amazona species are threatened with extinction (www.iucnredlist.org).

A. Barbadensis (photo 3.1) is an endangered parrot species distributed throughout the dry forests of the northeastern mainland of Venezuela, its islands Margarita and La Blanquilla and on the Dutch island Bonaire (Juniper & Parr, 1998). *A. Barbadensis* is the only Amazon species living exclusively in dry forests (Linares et. al., 2010). *A. Barbadensis* is medium sized (275-364 g) when compared to other Psittacidae (Williams, 2009).
IUCN classified the status of *A. Barbadensis* as vulnerable, meaning a chance of extinction of at least 10% within the next 100 years. The species endangerment is mainly caused by the illegal pet trade and habitat loss (Desenne & Strahl, 1991).

Photo 3.1: A Yellow-shouldered Amazon

Because of their diet, landowners often consider parrots as pests, which is why *A. Barbadensis* has been eradicated on Aruba in the 1950s. From *A. Barbadensis* dispersal pattern can be inferred that the species also existed on Curacao, but there are only vague mentions of its occurrence on Curacao in historical literature (Williams, 2009).

The global population size is estimated between 3.000 and 10.000 individuals (www.iucnredlist.org). The uncertainty is due to the lack of population statistics of *A. Barbadensis* on the mainland of Venezuela. The largest known population is found on the Venezuelan island Margarita with an estimation of 2400 parrots in 2001 (Rodriguez et. al. , 2004). On La Blanquilla there are an estimated 100 parrots (Rodriguez-Ferraro & Sanz, 2007). The current estimation of *A. Barbadensis* on Bonaire is 800 parrots (pers. comm. S. Williams), which is the highest number for the population since 1978 when a severe drought brought the population down to 100 parrots (Voous, 1983).
All these populations are considered as isolated from each other. Due to the small size of the island Bonaire and the home range of *A. Barbadensis* is the population considered to be unfragmented.
A. Barbadensis can be found anywhere on Bonaire, except in the south which is a windswept wetland with little suitable habitat for the parrots (Williams, 2009).

A. Barbadensis has four distinct life stages. Life starts as an egg which is incubated for on average 26 days. When the egg hatches the small parrot is known as a nestling, which means it is fully dependant on the parents for food. After two months the flight feathers are sufficiently developed and the young fledgling will leave the nest. The fledgling stage will last as long as the parrot will come back begging for food from its parents, ranging from one month to a year. The bird is fully fledged when it has reached independency and the parrot is considered an adult (Middleton and Prigoda 2001).

The female becomes reproductive at an age of three years (Sanz en Grajal 1998). The breeding season on Bonaire lasts from April until August. During the breeding season the parents do not allow other birds within the immediate vicinity of the nest. The nests are found in large boulders, in cliffs and in mature trees. During incubation and the first weeks of the nestling period the female remains in the nest and is dependent on the male for food. Then both parents will search for food to feed the nestlings (Williams, 2009).

As all parrot species, A. Barbadensis is a highly social species. Nests are often found in clusters, where the distance between the nests ranges from less than 100 meters to several kilometers. Nights are spent in roosts that can reach sizes of hundreds of individuals. The parrots also forage in groups (Williams, 2009; pers. obs.).

A. Barbadensis is faithful to roost locations and prefers roosts in the rural areas of Bonaire. During the drier periods, when there is less food available in the wild, the parrots move to urban roosts and forage in gardens and plantations (Williams, 2009).

The mating system of *A. Barbadensis* is monogamous and the pair bond is maintained year round (Williams, 2009).

3.6 Threats

A. Barbadensis faces a variety of threats on Bonaire, which are described in this section.

3.6.1 Poaching

Poaching is an activity where nestlings (photo 3.2) are collected in nature for the illegal pet trade.

The amount of poaching in an area depends on a multitude of factors: Public awareness, the number and attitude of the poachers, the social economic status of the country and the availability of an (inter)national market (Wright et. al., 2001).

The pet trade has severely affected many parrot species. Between 1991 and 1996, 1.215.020 parrot chicks were legally extracted from the wild, mainly from the Neotropics. This excludes the number of pre-export casualties which is estimated at 60%. Also not included are the national trade within the exporting countries and the illegal trade. 1.2 million captured parrots therefore is a great underestimation (Beissinger, 2001).

Photo 3.2: *A. Barbadensis* nestlings at various ages (Sam Williams)

In their study of studies Wright et. al. (2001) calculated an average of 30% of all chicks poached, based on the research results of 23 studies and 21 different neotropical parrot species. Poaching on islands was significantly lower than on the mainland with an average of 10%.

Until the approval of the Wild Bird Conservation Act (WCBA) in 1992 in the United States of America, endangered parrot species could be legally imported under certain conditions listed by CITES. The WCBA banned the import of all CITES listed parrots. This was a major achievement as the U.S. represented 50% of the parrot trade market.

Wright et. al. compared poaching rates before and after the new legislation and revealed a positive correlation between the legal and illegal trade: After banning the legal import of birds, the illegal import declined. In Europe however, the legal trade of parrots continued and in the first three years after the approval of the WBCA, 75% of all legally imported parrots had a European destination. Europe banned the import of CITES listed parrots in 2007 (http://publications.europa.eu).

The majority of parrot chicks are removed when they are fully feathered and have almost fledged. Parrots of this age are sold for values between 50 and 200 dollars on the black market, dependant on the species (Linares et. al., 2010). Linares et. al. (2010) did notice a trend towards the harvest of younger nestlings at ages of only 8 to 10 days. Parrots of this age are sold for 25-50 dollars on the market.

The effects of poaching on the population over time is hard to measure as most parrot species are long lived, so it would take many long term studies and a lot of confounding variables that have to be controlled for. An alternative is to use demographic models to simulate the effect of poaching on population size over time.

The capture of wild parrots on Bonaire has been an illegal activity since 1952, but there was no enforcement until the parrot registration campaign in 2002 when all parrots kept as pets were ringed. A total of 600 *A. Barbadensis* were ringed, which was more than the number of wild parrots at the time (Montanus, 2003).

As the nests are often deep down a tree cavity, poachers cut holes in them to extract the chicks. This method destroys the nesting habitat (Williams, 2009). There have been successful attempts to repair these nests, but this may be a futile investment as poachers know that *A. Barbadensis* pairs are faithful to their nest site after a previously successful nesting attempt and will revisit these sites (pers. comm. S. Williams).

The conservation program on Margarita Island, aimed mainly at the reduction of poaching, proved to be very successful. The population grew from 750 in 1989 to 2400 in the year 2001.But an unexpected negative side-effect was that the conditions for poaching were improved as well and the interest in this activity grew (Rodríguez et. al.,2004).

3.6.2 Urban development

The information in this chapter is extracted from the Ruimtelijk Ontwikkelingsplan Bonaire and the complementary Bonaire Strategische milieubeoordeling.

The government has proposed two different scenarios for the urban development of Bonaire. These scenarios have a lifespan of 10 to 15 years. Tourism is expected to grow from 75.000 stay over visitors per year now to 100.000 in 2020-2025. Tourists from cruise ships are set to a maximum of 100.000 visitors per year. The number of residents on Bonaire is expected to grow from 15.500 now to 25.000 in 2025.

Ruimtelijk Ontwikkelings Plan 1 (ROB 1) considers several developments, of which the most substantial are:

- 1.800 new houses within the existing contours of Kralendijk and Rincon;
- 1.200 new houses outside, but in between the lobes of Kralendijk and Rincon. Five locations are assigned, but no more than two are needed;
- Sustainable recreation outside the city contours;
- Extension of industrial estates on several locations;
- Designation of the water purification plant.

Ruimtelijk Ontwikkelings Plan 2 (ROB 2) is complementary to ROB 1 and includes the following developments:

- Urban and recreational development in an area between Rincon and Kralendijk;
- The construction of a bypass around Kralendijk;
- A golf course.

The visualizations of both scenarios are included in the appendix.

Dr. S. Williams has mapped the nesting and roosting sites of *A. Barbadensis* on Bonaire. This map is also included in the appendix. ROB 1 has a minor impact on these sites. The impact of ROB 2 is more severe.

3.6.3 Predation

There are few predators on Bonaire that feed on parrots. The only native predator is the Peregrine Falcon (*Falco peregrinus*), a bird of prey. The Peregrine falcon hunts on both fledglings and adult parrots, but as it is a winter migrant and present in small numbers, the effect on the population is small (Williams. 2009; pers. comm. Dr. S. Williams).
The introduced rats and cats on Bonaire predate on parrot nestlings. Several studies have shown the large negative impact introduced mammals have on parrot populations on islands (Snyder et. al., 2000; Engeman et. al., 2006; Blackburn et. al., 2004). Predator and prey usually engage in an evolutionary arms race, but when a predator is introduced this does not apply and the predator has an advantage over its prey. *A. Barbadensis* has not been selected on only choosing cavities that provide protection against predators. Instead, the nest site characteristics like the entrance height and size, the canopy cover and nest dimensions are varied on Bonaire (Williams, 2009). This often provides an easy access for the mammalian predators.

3.6.4 Competition

There are indications that interspecies competition for food resources is occurring on Bonaire, but in his three year field study Dr. S. Williams (2009) has not been able to conclude it. Intraspecific and interspecies competition for nest sites does occur.
A. Barbadensis and other bird species compete for high quality nest sites, which can sometimes lead to the death, but is often resolved by displays and vocalizations. Infanticide and the damaging of eggs by competing *A. Barbadensis* has also been observed (Williams, 2009).

3.6.5 Goats, donkeys and nest site limitation

Several studies have shown the devastating effect of introduced species on entire ecosystems (Clavero & Garcia-Berthou, 2005; Blackburn et. al., 2004).
There are two exotic grazing mammals present on Bonaire: feral goats and donkeys. Both were introduced by early colonists in the 16th century. These invasive mammals have prevented the regeneration of the vegetation after the felling of trees, centuries ago (Freitas, et.al., 2005).
Today the vegetation on Bonaire still is heavily degraded, which is demonstrated by few tall trees and low tree coverage (Williams, 2009). The vegetation is also dominated by species equipped with a defensive exterior, like spines and thorns, as only these species are able-bodied to the intensive grazing (pers. obs.)

The size of the breeding population is relatively small compared to the population on Margarita; 21,5% (based on a population size of 650 parrots) and 33% respectively (Williams, 2009; Sanz & Rodríguez-Ferraro, 2006). A non breeding population of almost 80% is a reason to assume *A. Barbadensis* is nest site limited, caused by a lack of suitable trees. Trees have to reach ages of at least 140-200 years to contain cavities large enough to fit an adult parrot (Koch et. al., 2008; Carrit, 1999). Goats and donkeys therefore appear to maintain the limited number of nest sites.

Dr. S. Williams (2009) conducted a field study on the subject and made an inventorisation of the number of available nest sites on Bonaire. *A. Barbadensis* occupied only 30% of all suitable cavities. This could mean *A. Barbadensis* is not nest site limited at all, but it could also mean not all requirements which make a cavity suitable are known (Williams, 2009). For example, the distance to food resources and to other cavities was not taken into account.

When *A. Barbadensis* is in fact nest site limited, then the focus should be on increasing the number of nest sites, as other conservation measures that improve survival in any life stage would only result in enlarging the non breeding population (pers. comm. Dr. S. Williams).

Besides the nest site limitation, the goats and donkeys also cause a food resource limitation. In drier periods the majority of the parrots move to urban roosts to forage in gardens and plantations. This generates a conflict with landowners and *A. Barbadensis* die in car accidents and collide against windows (Williams, 2009). When there is more food available in the rural areas, the parrots might not, or in a lesser degree, have to visit the urban environment.

3.6.6 Climate

The climate on Bonaire is semi arid, which is characterized by a year round high temperature and low rainfall. The average temperature is 28˚C with small (± 3˚C) seasonal fluctuations. About 51% of the 463 mm annual rainfall falls during the rainy season in October, November and December. The islands Curacao, Aruba and Bonaire show a great variability in the amount of rainfall per year: the standard deviation is larger than the mean. The variation is caused by the El Niño southern oscillation (Martis, 2001). This oscillation, a continuous warming and cooling, exists in the ocean atmosphere across the tropical Pacific Ocean and has a great effect on the weather worldwide (http://www.pmel.noaa.gov).

Renton & Salinas-Melgoza (2004) revealed a correlation between El Niño and Lilac-crowned parrot (Amazona Finschi) productivity. More nestlings were counted in years with a higher amount of rainfall in the preceding rain season.
Higher productivity is caused by the availability of more fruits after a season with above average rainfall (Guevara de Lampe et. al. 1992), which results in heavier females. The females can subsequently convert the nutrient reserves in a larger clutch size (Ankney & MacInnes, 1978; Newton et. al., 1983) A positive correlation between clutch size and precipitation in the preceding rain season has also been observed in the *A. Barbadensis* population on Margarita island (Sanz & Rodriguez-Ferraro, 2006). The rainfall prior to

the breeding season relates positively to the availability of plant resources in the dry season as well (Renton & Salinas-Melgoza, 2004).
When rainfall is very low during the breeding season the hatchability lowered, probably because of incubation inconsistency as the male alone cannot deliver a sufficient amount of food (Sanz & Rodriguez-Ferraro, 2006).

Productivity is not the only parameter influenced by climatic variability. The use of rural roosts is positively related to the rainfall in the previous month. Almost 90% of the population was counted at urban roosts after a dry month. The urban environment is hazardous for parrots as they collide with cars and windows. They are also considered as a pest by landowners as *A. Barbadensis* forages in irrigated gardens and plantations. Conflicts can escalate into injuring or killing the parrots (Williams, 2009).

3.6.7 Disease

There is no information available on the occurrence of diseases on Bonaire. Sans & Rodriguez (2006) reported the results of a veterinary study conducted on a group of *A. Barbadensis* by Hoogesteyn & Diaz (1993) on Margarita island: No diseases common for parrots like psittacosis and New Castle disease were found. Hardly any ectoparasites were found as well.

3.7 Opportunities

This part of the thesis describes the opportunities to resolve some of the threats described in the previous chapter.

3.7.1 Public awareness

A vital aspect of a conservation plan should be public awareness. This is where the root of the problem can be addressed. Tourists and local inhabitants often do not realize the consequences of their actions concerning parrots and they are also often unaware of the endangered status of *A. Barbadensis*. A survey on Bonaire revealed that 45% of the fruit growers were unaware of the parrots endangerment (www.echobonaire.org). When the attitude and the behaviour towards *A. Barbadensis* is changed, poaching rates will likely drop, conflicts between landowners and the parrots will occur less frequently (Linares et. al. 2010) and decision makers will take their threatened status into account.
Awareness can be generated in many ways. On Margarita island, environmental educational programs have been developed, an annual parrot festival is hosted, environmental days have been introduced and *A. Barbadensis* is used as the islands conservation symbol (Sanz & Grajal, 1998). The educational program is given on elementary schools as children are collectively reachable and they are only a few years younger than poachers often are (Linares et. al. 2010).
The foundation Echo Bonaire, led by Dr. S. Williams, has been raising awareness with similar methods, organizing parrot parades and festivals (www.echobonaire.org).

3.7.2 Reducing poaching

Nest guarding

The protection of nests has proved to be an effective way to reduce poaching in several conservation programs (Wright et. al. 2001) . Poaching resulted in a loss of all *A. Barbadensis* nestlings on Margarita island in 2003. With 24 hour surveillance in 2004, the poaching percentage was reduced to 56% (Linares et. al. 2010).

Drawbacks of nest guarding are the high expenses of active patrol and the large areas that have to be covered. Nest guarding therefore, is not considered as a sustainable strategy (Wright et. al. 2001).

Assisted breeding

Assisted breeding refers to the act of moving parrot chicks to a secure location every night, rendering poaching impossible. The nestlings can only be moved when the mother is not present. This occurs after sunset and before sunrise from 30-40 days after hatching, when the mother spends the nights in roosts (Linares et. al., 2010).

Poaching risks are reduced and the expenses are less than captive breeding would be. This method is of course very time consuming and should only be used when poaching rates are high. Because of the costs and the time consumption this is not a sustainable strategy for the long term as well.

Foster nests

Nesting locations vary in their conspicuousness. Nests are more likely to get poached when they are closer to roads for example. Nestlings in high risk locations can be removed and cross fostered to a safer nest. This method is more successful than captive breeding or nest boxes, but also depends on funding and intervention stays necessarily (Linares et. al., 2010).

Export prevention

The parrot registration campaign in 2002 has diminished the demand on Bonaire for illegally captured parrots, as owners of unregistered *A. Barbadensis* face prosecution and the parrots will be confiscated. Poachers have to export the birds now to sell them. The export of parrots can be prevented by the efficient checking of boats leaving the island.

Ecotourism

The International Ecotourism Society defined ecotourism as: ‘Responsible travel to natural areas that conserves the environment and improves the well-being of local people’

(www.ecotourism.org).
The economy of Bonaire thrives on tourism, but the income gained from tourism is heavily skewed towards European and American inhabitants. (Williams, 2009). Ecotourism aims to balance the profits gained from tourists. As a consequence, the local people do not need to resort to illegal activities like poaching anymore.
Sustainable tourism also helps to maintain the breeding and roosting sites used by *A. Barbadensis*.

3.7.3 Captive breeding

Captive breeding is only a useful method for (critically) endangered species and should not be used when there are viable alternatives. Captive breeding is expensive, needs specialized workers and (consistent) breeding success is not guaranteed (Derrickson & Snyder, 1992; Snyder et. al., 1996). It should always be used as a short term solution as domestication is likely to happen in the long term (Snyder et. al., 1996).
The release of captive bred parrots is problematic as well, as they often lack a fear of humans and introduced birds can transfer diseases to the resident population.
When a parrot breeding facility also has a commercial purpose, then the laundering of illegally extracted chicks is a risk factor (Wright et. al., 2001).

3.7.4 Nest repair & artificial nest boxes

The nests of the parrots are often deep down a cliff or tree cavity. Poachers throw rocks in the cavities to check whether or not the cavity is occupied by a nest of parrot chicks. Trees are cut open in order to extract the chicks from the nest. These nests cannot be used by *A. Barbadensis* anymore unless they get repaired. Nest repair proved to be relatively successful in Williams' (2009) field study as 3 out of 10 repaired nests were reused in the following breeding season.
None of the 12 artificial nest boxes were used during a timeframe of three successive breeding seasons. This is no surprise as getting parrots to accept nest boxes is difficult and can take many years (Sanz et. al. 2003). Sanz (2003) had a success rate of 5.6% with the use of 16 artificial nest boxes during a period of 7 years on Margarita island. Poaching was more frequent in nest boxes because of their conspicuousness and the easy access through an observation door. Nest repair was more successful: All of the 15 repaired nests were reused in later breeding seasons.
These methods are only of use when the poaching rate is simultaneously reduced.

3.7.5 Eradication of exotic mammals

Exotic species can disrupt entire ecosystems. They can grow into invasive species, because natural enemies are absent. Introduced feral goats are known to be destructive to island ecosystems. The Galagapos islands once had 140.000 feral goats, but they were all slain over a five year period, as a part of the largest eradication project against invasive species ever undertaken (Guo, 2006).

The growth of the *A. Barbadensis* population on Bonaire is probably limited by the number of nest sites due to the intensive grazing of the many goats and donkeys that are freely roaming over the island (chapter 3.6.5).
When these mammals are eradicated the vegetation can regenerate and over time, the ecosystem will restore to its natural balance. *A. Barbadensis* will benefit by the increase of food resources and nest sites through hollow formation.
The exotic rats and cats could be eradicated as well to increase female reproduction and chick survival.

3.7.6 Reintroduction

Species are more likely to become extinct on islands than on the mainland (Ferraro & Sanz, 2006). *A. Barbadensis* is distributed almost exclusively on islands. When *A. Barbadensis* is reintroduced to Aruba and Curacao, islands where the parrot once existed, extinction is less likely to happen. These populations could subsequently form a metapopulation as the islands are located relatively close to each other.
The reintroduction program should be part of a conservation program, aimed at raising awareness and habitat protection. Birds originating from the international pet trade should be quarantined for up to 2 years, because they might carry exotic diseases. Finally, the area should have some degree of protection for the reintroduction program to be succesful (Sanz & Grajal, 1998).

4 Parameter values

The literature study, described in the previous chapter, has resulted in estimations on different parameters both describing and affecting the population of Yellow-shouldered Amazones (*Amazona Barbadensis*) on Bonaire.

Climate

The climate affects the survival rates of chicks, juveniles and adults and additionally the female reproduction. The annual climate varies randomly in the model between the values 0 and 1. Each of these extremes corresponds with the extremes of the intervals described at survival and reproduction below.

Population size at year 0 (present): 800 parrots

This number represents the most recent population count performed by Echo Bonaire in 2011 (pers. comm. Dr. S. Williams).

Reproductive population: 140 parrots

Williams (2009) estimated a breeding population on Bonaire of 140 parrots.

Population ceiling: -

The number of birds is only limited by the number of available nest sites.

Number of nest sites: 70 nests

This number assumes the parrot population on Bonaire is nest site limited and currently nest sites are occupied at maximum capacity.

Annual female reproduction: 1.46 (±0.552 S.D.) - 2.18 (±0.824 S.D.) chicks

Williams (2009) estimated the reproduction at 2.55 ± 0.964 S.D. (brood size at hatching with at least on chick). This number does not include the 20 nests (out of 70) that failed during incubation. Hatching failure is caused by several factors:

- Competing birds inflict damage to eggs;
- Predation of eggs;
- A suboptimal climate results in incubation inconsistency expressed in lowered hatchability;
- Probable existence of inbreeding depression on Bonaire expressed in lowered hatchability.

When incubation failure is included, the reproduction is estimated at 2.55*(50/70) = 1.81 chicks. The climate during the field study of Williams (2009) is considered as average. Climate is assumed to result in the failure of 20 nests under the worst conditions and no failure under optimum conditions. The predation of eggs is assumed at a constant of 10 nests. Optimum climate conditions therefore result in

2.55*(60/70) = 2.18 chicks and worst climate conditions result in 2.55*(40/70) = 1.46 chicks.
Inbreeding depression and the damaging of eggs caused by competitors is included in the standard deviation. Another factor explaining the large standard deviation is the patchy distribution of food resources resulting in varied nesting success dependant on the location of the nest (Williams, 2009).
The standard deviation changes proportionally:
0.964/2.55 = 0.378 (the relation between reproduction and the standard deviation)
1.46*0.378 = 0.552 S.D.
2.18*0.378 = 0.824 S.D.

Chick stage: ***0-1 years***
Juvenile stage: ***1-3 years***
Adult stage: ***3 years and older***

METAPHOR monitors the population once every year. That is why the life cycle deviates from the stages described in chapter 3.5 (i.e. nestling, fledgling, adult).
Chicks differ in survival rates compared to juveniles and adult. Juveniles and adult share the survival rate and only differ in reproduction (i.e. juveniles are not capable of reproducing and adults are).

Annual probability of chick survival: ***0.46 (± 0.10 S.D.) - 0.76 (±0.17 S.D.)***

Chick survival is composed out of

- chick predation: 0.1 (a value from Sanz-Rodriguez-Ferraro (2006) as there is no predation data available for Bonaire)
- poaching: 0.14 (7 out of 50 nests were poached (Williams, 2009))
- climate mortality: 0-0.3 (estimated random climate stochasticity)

The standard deviation conveys the demographic stochasticity and is also proportional to the survival rate. The standard deviation is 0.11 for a survival rate of 0.51 (Zambrano, 2011) and therefore is:
0.11/0.51 = 0.22 (the relation between chick survival and the standard deviation)
0.46*0.22 = 0.10 S.D.
0.76*0.22 = 0.17 S.D.

Annual probability of juvenile and adult survival: ***0.80-0.95***

There is no empirical data available on juvenile and adult survival of *A. Barbadensis* in the wild. A survival probability of 0.80-0.95 (0.15 random climate stochasticity) is used from Rodriguez et. al (2004) as they also did a viability analysis on *A. Barbadensis*. These survival rates correspond with a life expectancy of between 5 and 20 years.
There is no standard deviation included, because all stochasticity is expressed in the interval of the survival rate caused by climatic fluctuations.

Migration: ***Absent***

The populations on the Caribbean islands and on the mainland of Venezuela are all considered as isolated and thus are the population dynamics determined by survival and reproduction (Lack, 1966).

5 Sensitivity analyses

There are several factors affecting the Yellow-shouldered Amazon (*Amazona Barbadensis*) population on Bonaire. In conservation biology, it is crucial to know which factors the species is most sensitive to. METAPHOR is used to assess this sensitivity. Each factor was separately changed in intensity to measure the effect on the population after a period of 100 years. A period of 100 years was used to avoid measures in the burn in period. Every change in intensity was repeated 100 times to generate a reliable average of this stochastic process.

Box plots were used to display the distribution of the population size at each intensity.

The rectangle of the box plot shows the interquantile range. The lowest line of the box is the 25th percentile and the highest line the 75th percentile. The middle line represents the median. The whiskers are set at 1.5 times the interquantile range, except when there are no values this far of the median. Values that are shown as a circle are outliers (at a distance of more than 1.5 times the distance of the interquantile range) and values that are shown as stars are extremes. (at a distance of more than 3 times the distance of the interquantile range). The numbers next to the circles and stars refer to their position in the SPSS file (Huizingh, 2006).

Appendix 5 displays the tables listing the input in METAPHOR for every analysis.

Appendix 6 displays the level of significance when comparing the averages between intensities. When a comparison is significant it means that the population is to a certain degree sensitive to changes in the variable for that analysis.

The sensitivity analyses are classified in four categories: Survival, reproduction, number of nest sites and climate.

5.1 Survival

Sensitivity to poaching intensity

This analysis was carried out under the assumption that the number of nesting cavities remained constant, thus the effects of poachers is limited to the poaching of nestlings and the effects of destroying tree nests is not included.

The current poaching intensity is estimated to be 14% (=0.14) of all hatched and surviving nestlings. Figure 5.1 reveals the effect of less and more poaching pressure. The extinction threshold appears to be at a poaching rate of 50% as persistence beyond this rate is unlikely.

All changes in poaching rates result in significant changes in population size, except for the size at 70 and 80% poaching rates as the population is extinct.

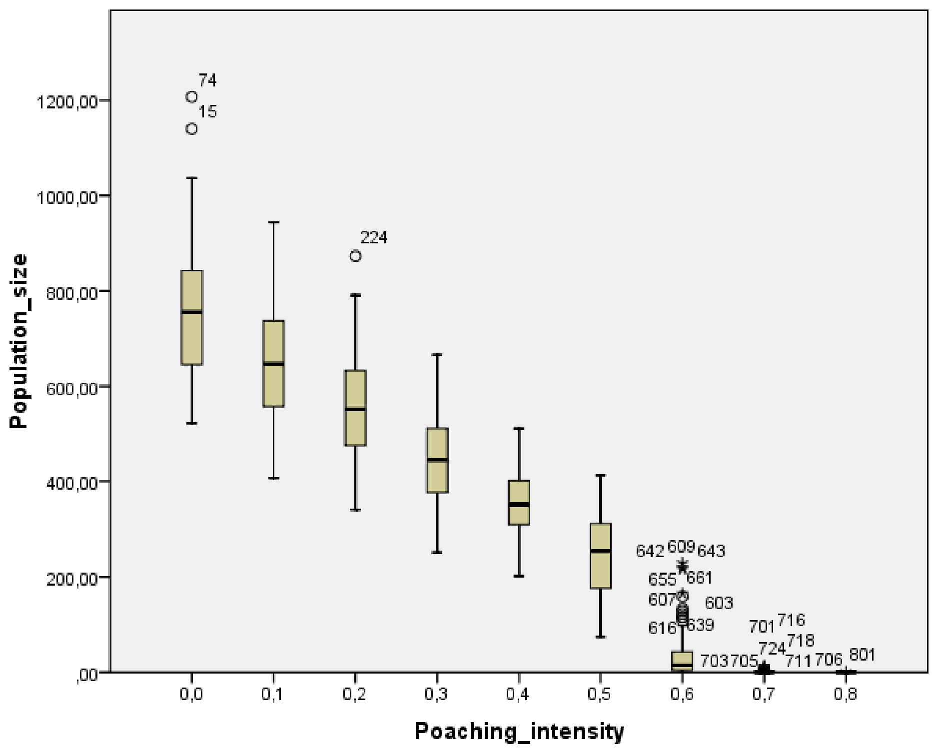


Figure 5.1 The effect of different poaching intensities on the population size after 100 years

Sensitivity to predation intensity

Predation only applied to chicks in this analysis. The current predation intensity by rats and cats is 10% (=0.10). The results displayed in figure 5.2 are relatively similar to figure 1.2 as both factors seize to the same parameter (chick survival). Because of the limited amount of time for every analysis and because predation risk is not expected to reach large numbers does the figure not contain the entire range of intensities.

Every change in intensity results in a significant change in population size.

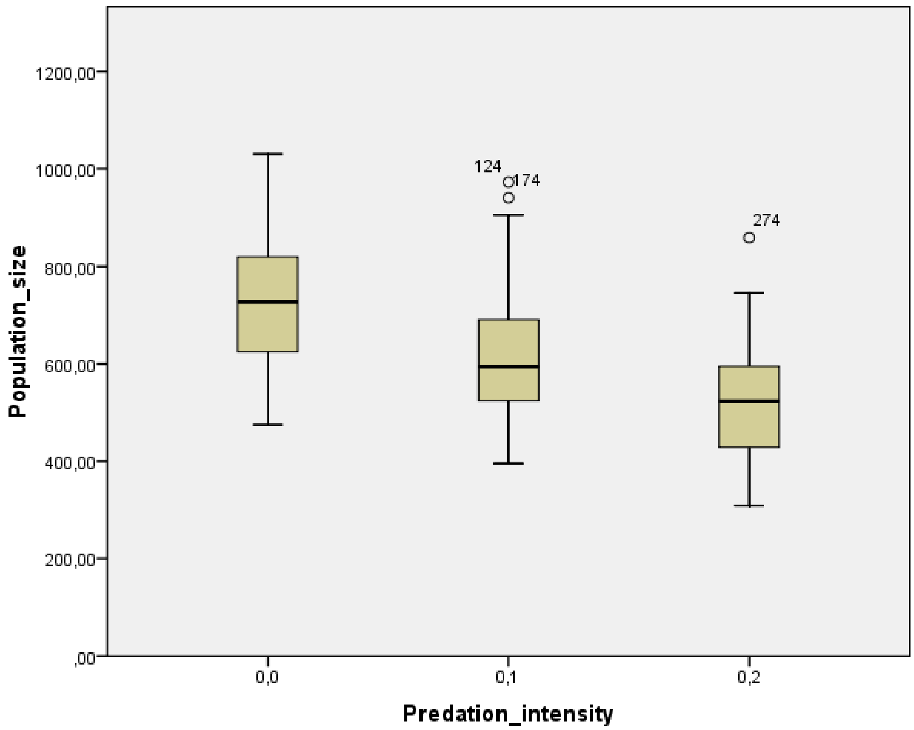


Figure 5.2 The effect of different predation intensities on the population size after 100 years

Sensitivity to chick survival

Figure 5.3 displays the effect of differences in chick survival rates on the population size. The population declines roughly linearly until the range of 0,38-0,62 and declines at a faster rate when chick survival lowers. The box plots at the high end of the survival spectrum are distorted, because the range cannot exceed 1,0. This caused a non significant result when comparing the intervals 0,68-1,00 and 0,75-1,00. All other comparisons differ significantly.

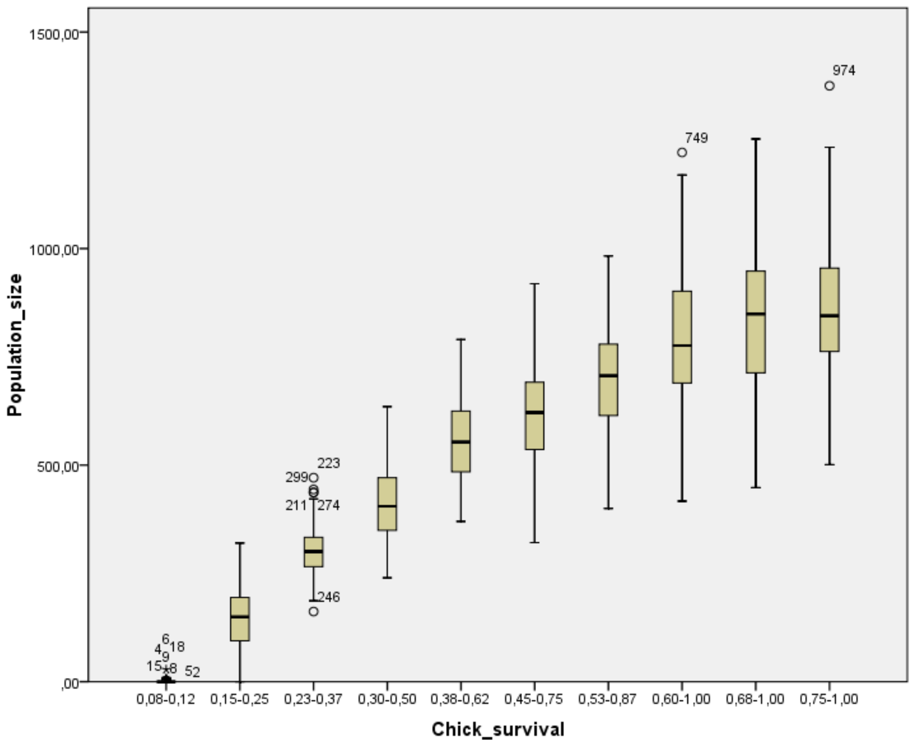


Figure 5.3 The effect of changes in chich survival on the population size after 100 years

Sensitivity to stochastic intensity of chick survival

The current standard deviation at the average of chick survival is 0,13.

Figure 5.4 shows a very mild sensitivity to changes in the standard deviation of chick survival. The distribution of the population size grows when the standard deviation increases and the population size drops slightly.

The average population sizes at S.D. 0,13 and 0,51 differ significantly (p=0.03). Other comparisons do not.

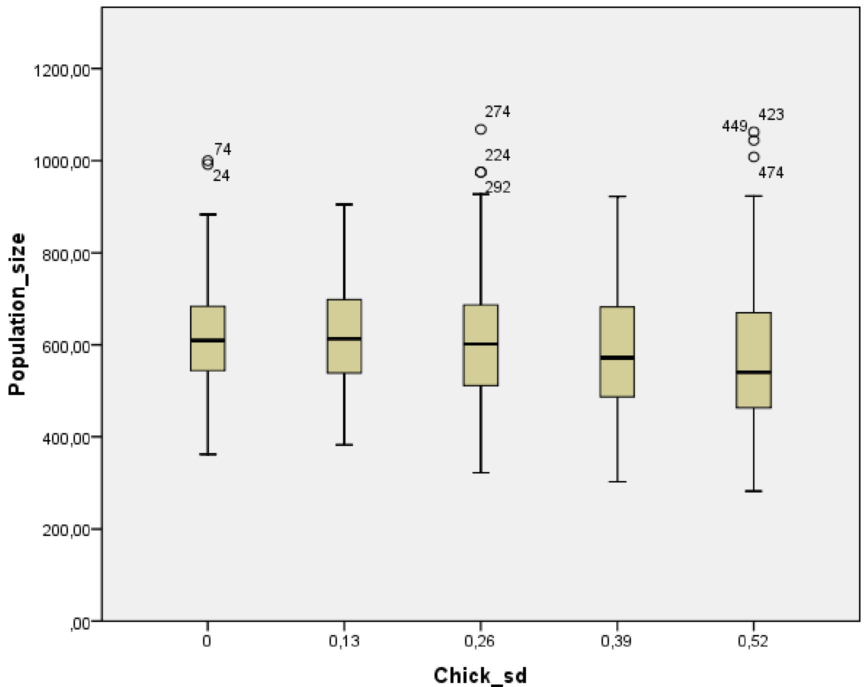


Figure 5.4 The effect of different standard deviations of chick survival on the population size after 100 years

Sensitivity to juvenile and adult survival

The survival of juveniles and adults is grouped together in this analysis, because they do not react differently under threats. Figure 5.5 shows a high sensitivity to survival of juveniles and adults. An average survival below 0.8 (= 5 years of age) will lead to extinction within 100 years. A comparative analysis revealed significant differences between all surviving categories.

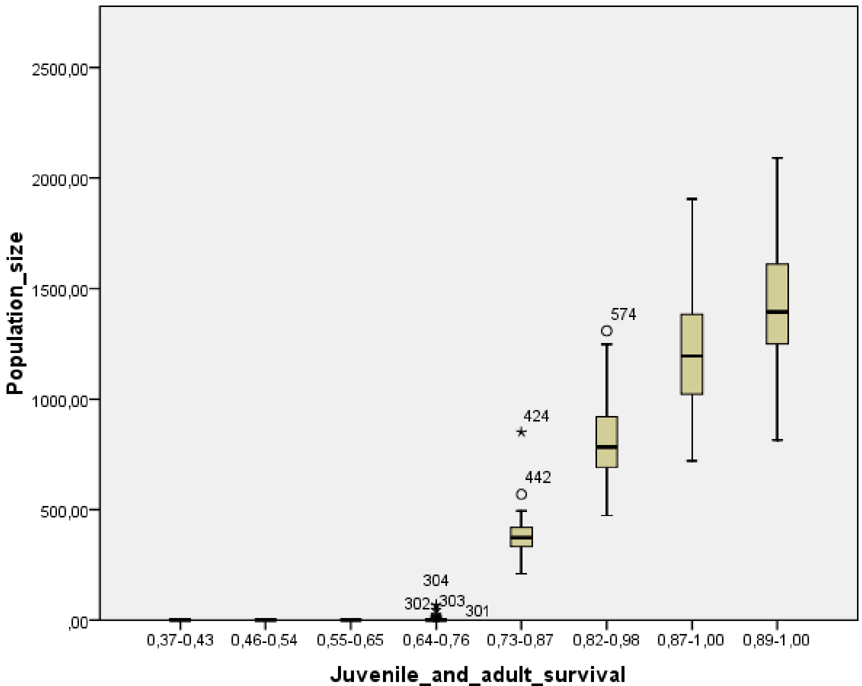


Figure 5.5 The effect of changes in juvenile and adult survival on the population size after 100 years

5.2 Reproduction

Sensitivity to reproduction and stochasticity in reproduction

Figure 5.6 displays the sensitivity to changes in female reproduction and its stochasticity. The top figure reveals a linear relationship between population size and reproduction untill the reproduction drops to 0,8-1,2. A further decrease in reproduction results in a population of less than 100 individuals. Comparisons revealed significant differences between all intervals. The bottom figure shows an insensitivity to stochasticity in female reproduction. The distribution of the METAPHOR output values increases, but the median remains stable at ± 600 parrots. Significant differences were only obtained when comparing the different standard deviations to 2.07 S.D..

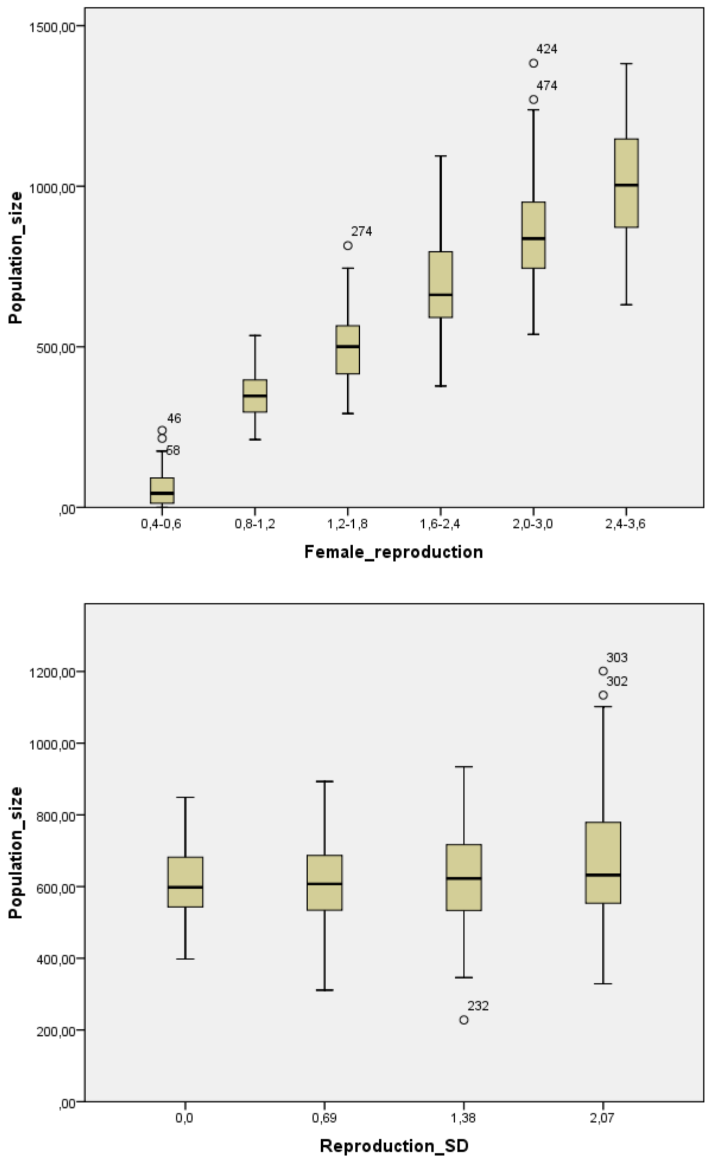


Figure 5.6 Top: Sensitivity to female reproduction. Bottom: Sensitivity to stochastic intensity of female reproduction.

5.3 Number of available nests

Sensitivity to changes in the number of nesting cavities

A. Barbadensis nests in cliffs, boulders and tree cavities. The first two are constant, but the number of tree cavities varies under the influence of the exotic mammals and the poachers.

Dr. S. Williams (2009) measured an equal distribution of nests between tree nests and nests in rock cavities. 35 Cavities would remain on Bonaire when poachers cut open all tree cavities. This is therefore the lowest number in the range of available nests. The number of nests could expand beyond the current number of 70 nests when the vegetation restores after the eradication of goats. The range ends at 140 which is twice the number of currently available nests. Figure 5.7 shows a stable linear relationship between the number of nests and the population size. The comparative analysis revealed high significances between the different numbers of available nest sites.

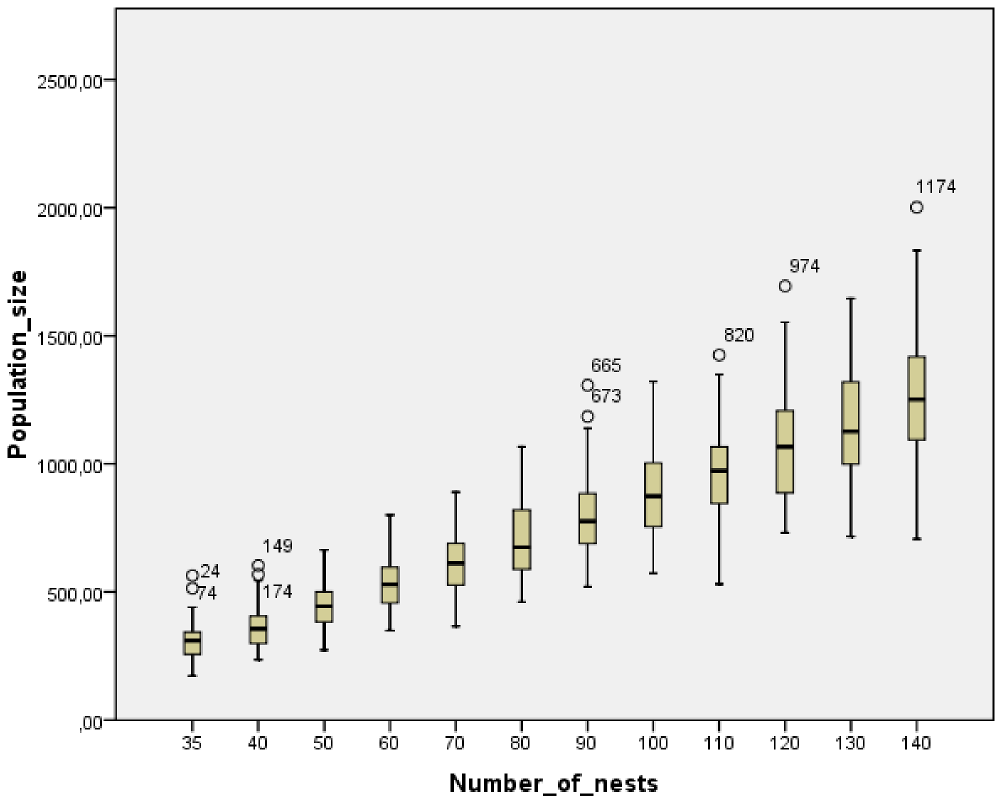


Figure 5.7: The effects of changes in the number of nesting sites on the population size after 100 years

5.4 Climate

Sensitivity to climate change

In all but this analysis and the climate scenarios does the climate parameter changes randomly from year to year between 0 and 1. This affects both survival and reproduction. This analysis reveals the sensitivity of the population when the climate changes to more optimal conditions (wetter) or worse conditions (drier) for a long period. Figure 5.8 displays an exponential relationship between the climate and the population size, where the population is more sensitive to more optimal conditions.

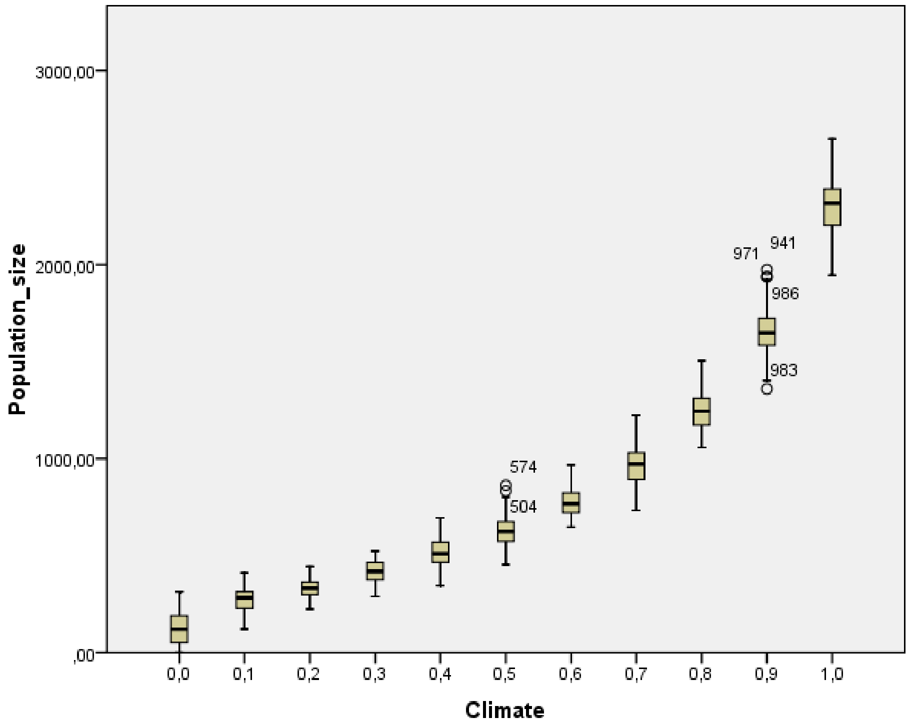
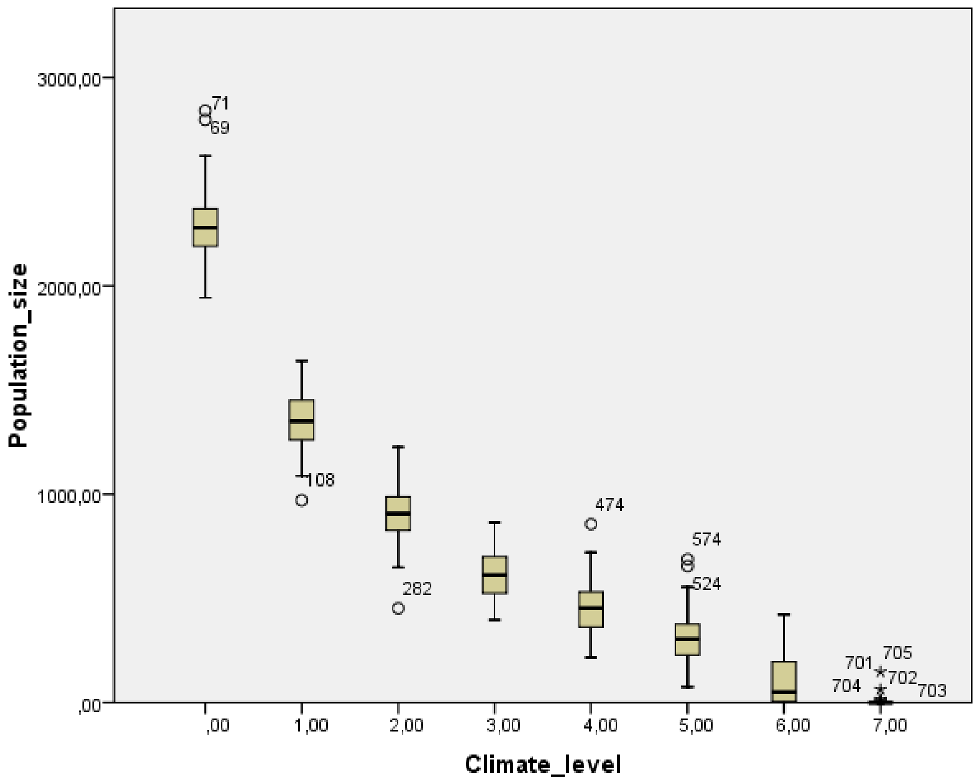


Figure 5.8: The effects of a long term and constant change in climate on the population size after 100 years

Sensitivity to change in climate effects

The exact effect of climatic conditions on the survival and reproduction of *A. Barbadensis* has not yet been determined. This analysis therefore investigates the sensitivity of the population to changes in intensity of the effects caused by climatic stochasticity. There are 8 different climate levels ranging from 0 (no effects) to 7 (highly severe effects). The current estimated effect the climate has on the population is climate level 3. The specifics for every climate level are listed in appendix 5. Figure 5.9 shows the relation between changes in climate impact and population size. All comparisons between the medians were highly significant. The population appears to be most sensitive between low impact levels.



5.9 The effect of different climate levels on the population size after 100 years.

6 Scenarios

Simulation models can be used to generate the population dynamics over time for different scenarios. Decision makers can use the model to predict how different management options affect the population. This chapter covers a limited number of straightforward scenarios mainly for exploratory and demonstrational purposes, because the number of possible scenarios and combinations of scenarios are potentially limitless.

The effect of each scenario is expressed in a population size of Yellow-shouldered Amazon (*Amazona Barbadensis*) parrots over time. The duration of each scenario is 200 years and was repeated 100 times to generate a reliable average for every year. Each graph displaying the average for every year is accompanied by two lines, representing the standard deviation in both directions.

The input data for METAPHOR is listed in appendix 7.

The chapter starts with the current (baseline) scenario, which is followed by a poaching scenario. Next up are the climate and urban developmental scenarios. The chapter ends with different conservation scenarios.

6.1 Current scenario

The first scenario counts as the baseline scenario as it describes the population dynamics over 200 years from today under current conditions. The population stabilizes after the burn in period at ± 650 parrots (figure 6.1). Coincidentally, this is the exact number counted and used in Williams (2009).

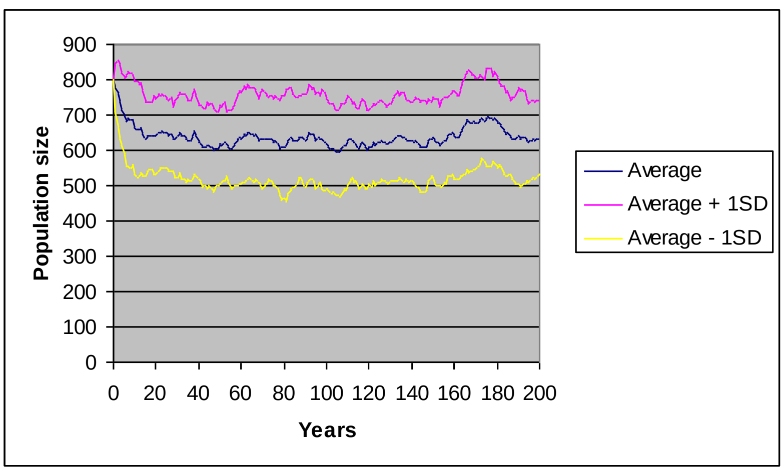


Figure 6.1: The population dynamics of *A. Barbadensis* under current conditions.

6.2 Poaching scenario

Tree nests are often found deep down in a tree with a narrow entrance hole. Poachers gain access to these nests by cutting a hole at the height of the nest, simultaneously destroying the nesting habitat. The poaching scenario shows the effects of this detrimental method on the population size at an annual poaching rate of 14%. As was previously mentioned does half of the nesting habitats on Bonaire consist of tree nests, which means that every year 7% of the nests are lost until there are no more tree nests left. Figure 6.2 reveals a steep decline, stabilizing when there are only cliff- and boulder nests left, at a population size of ±300 parrots.

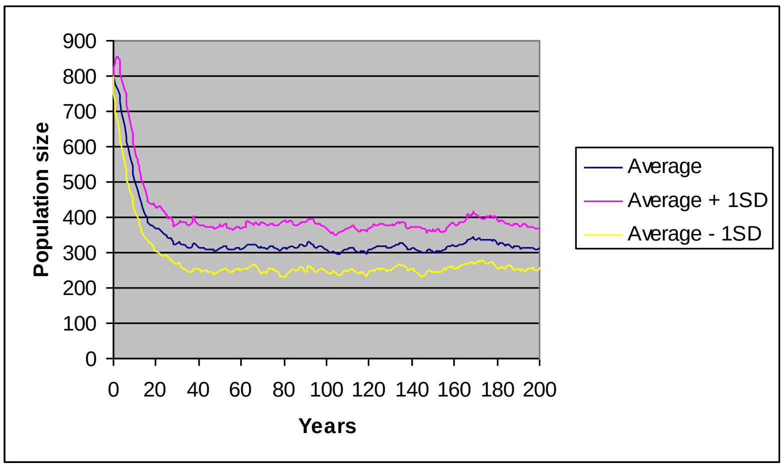
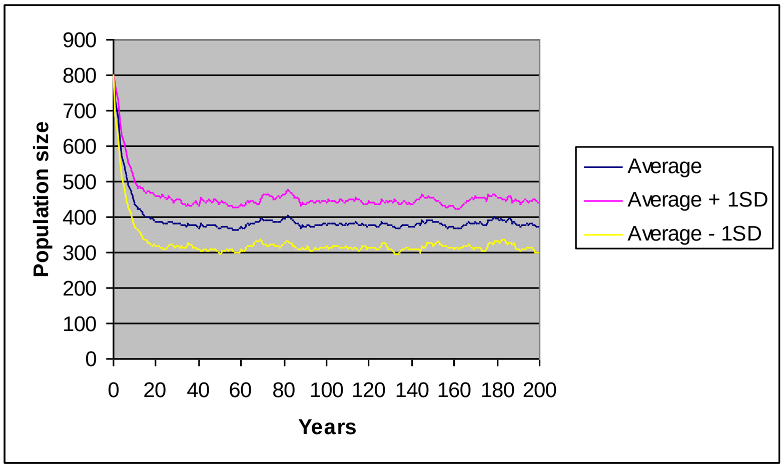


Figure 6.2: The population dynamics of *A. Barbadensis* over 200 years when nests are lost due to poaching activities

6.3 Climate scenarios

The two scenarios displayed here focus on climate change. The top figure reveals how a drier climate affects the population. This is achieved in METAPHOR by limiting the climate parameter to vary randomly between 0 and 0.5 which has a direct influence on survival and reproduction. A drier climate results in a population size of ±400 parrots. The bottom figure displays the effects of a wetter more optimal climate change. The climate parameter varies between 0.5 and 1.0 in this scenario. These conditions lead to a population size of 1100 parrots which is an increase of 300 parrots compared to the current population of *A. Barbadensis* on Bonaire.



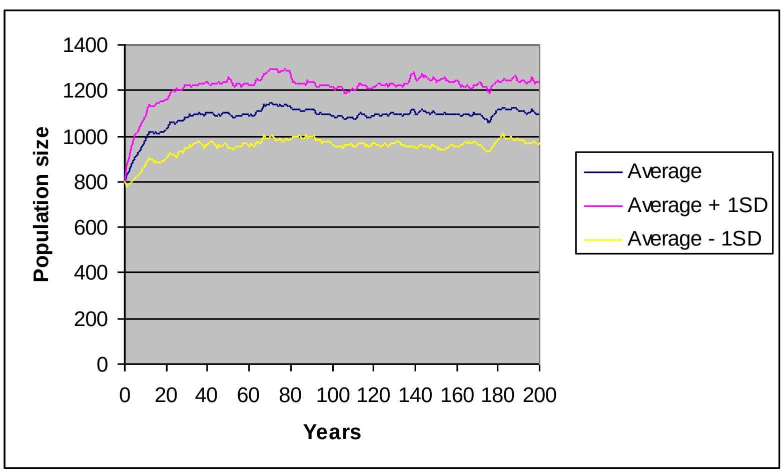


Figure 6.3 Top: The population dynamics of *A. Barbadensis* over 200 years when the climate changes to drier conditions. Bottom: The effects of a wetter climate on the population size over a period of 200 years.

6.4 ROB scenarios

The government has to decide between two possible scenarios regarding the urban development of Bonaire (chapter 3.6.2).

The effect of ROB 1 on the parrot population is roughly estimated by comparing the map of ROB 1 (appendix 2) to the map revealing the locations of all nesting and roosting sites (appendix 4). An equal distribution of cliff- and tree nests at each nesting site is assumed during the following calculations.

There are 70 nests, of which 35 are cliff nests and are therefore not affected by urban planning. The remaining 35 tree nests are spread out over 19 breeding locations (appendix 4), which results in an average of 1.84 tree nests at each location. The ROB1 scenario is planning to build new estates at the expense of an estimated half nesting site (=0.92 nests). But as only 2/5 of the designated areas will actually be exploited for urban development, is 0.92 nests lost reduced to:

0.92*0.4 = 0.368. ROB scenarios have a lifespan of 15 years, so the number of nests lost per year is 0.368/15 = 0.025. The scenario employed here assumes a continuous proceeding urban development for the next 200 years.

The complementary scenario ROB 2 is planning to eliminate an additional two breeding sites (3.68 tree nests).

The number of nests lost per year due to ROB 2:

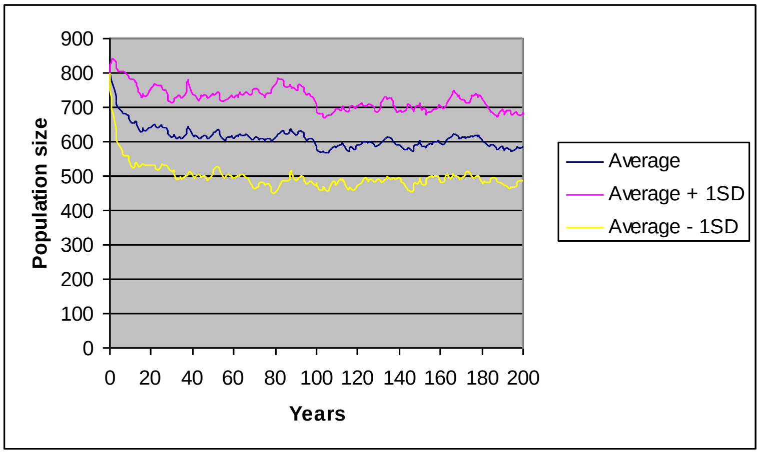
0.368+3.68 = 4.048 / 15 = 0.270.

The tree nests at the 6 breeding sites located in the national park are not threatened by urban development. Continuous urban development over time would eventually result in the disappearance of all unprotected tree nests at the remaining 13 locations.

13*1.84 = 24. The number of nests on Bonaire will therefore not drop below 70 – 24 = 46.

Both scenarios have a negative impact on the population size of *A. Barbadensis* as figure 6.4 shows but whereas the impact of ROB 1 is minor, is the impact of ROB 2 substantial; halving the population after 200 years.

ROB 1 scenario



ROB 2 scenario

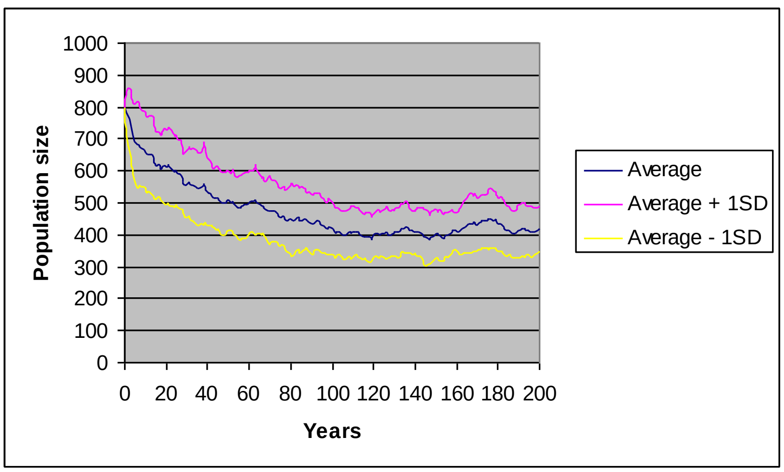


Figure 6.4: The effect of different scenarios regarding the urban development of Bonaire on the population size of A. Barbadensis.

6.5 Conservation scenarios

There are several possible solutions to enhance the future prospects of the *A. Barbadensis* population on Bonaire. This chapter discusses the effects of several conservational measures separately and concludes with an integrated conservation scenario which includes all previously mentioned measures. There is no urban development in any of the conservation scenarios.

No goats and donkeys scenario

An eradication program of all introduced feral goats and donkeys on Bonaire is estimated to result in a direct increase in parrot survival as the vegetation will benefit greatly when the goats are removed and thus the availability of food resources would increase considerably, affecting parrot survival in all life stages. Increased juvenile and adult survival is caused by a decrease in mortality as a result of less frequent visits to urban areas to forage (chapter 3.6.5). Chick survival increases because starvation is less likely to happen. Furthermore, female reproduction increases as well, as the influence of climatic stochasticity on the weight of the females declines.

The eradication program will result in the population size increasing to ± 1300 parrots in the short term (figure 6.5).

Figure 6.5 also displays a steep increase in population size after 140 years, which is caused by a growth in the number of tree cavities, increasing the size of the breeding population.

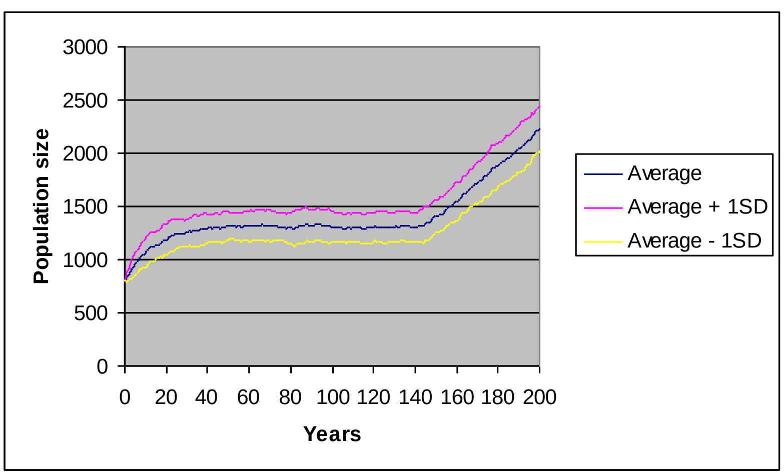


Figure 6.5: The effects of a goat and donkey eradication program on the population size of *A. Barbadensis*

No poaching scenario

Poaching is less common on islands than on the mainland (chapter 3.6.1). Williams (2009) data on poaching is scanty, but the conclusion remains the same. The small amount of poaching is also reflected in a relatively small effect on the population size (figure 6.6), increasing on average with ± 100 parrots compared to the current scenario.

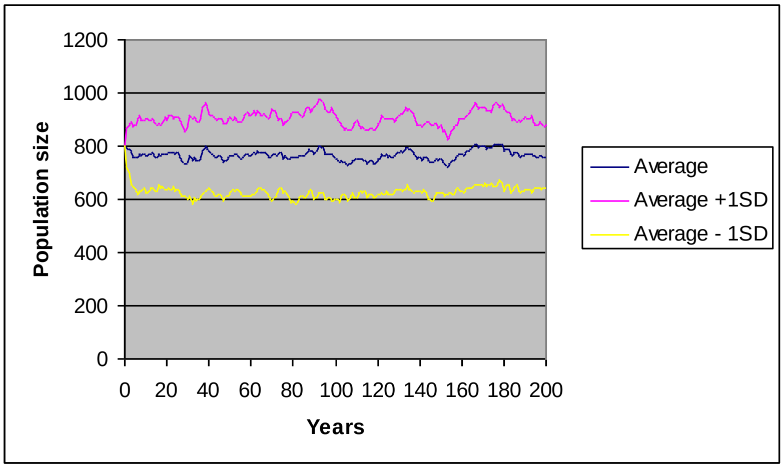


Figure 6.6: The effects of eliminating poaching on the population size of *A. Barbadensis*

No rats and cats scenario

The introduced rats and cats on Bonaire predate on the eggs and chicks of *A. Barbadensis*. Elimination of these species therefore results in an increase in female reproductivity and enhanced chick survival. Figure 6.6 reveals an average population of ± 825 parrots.

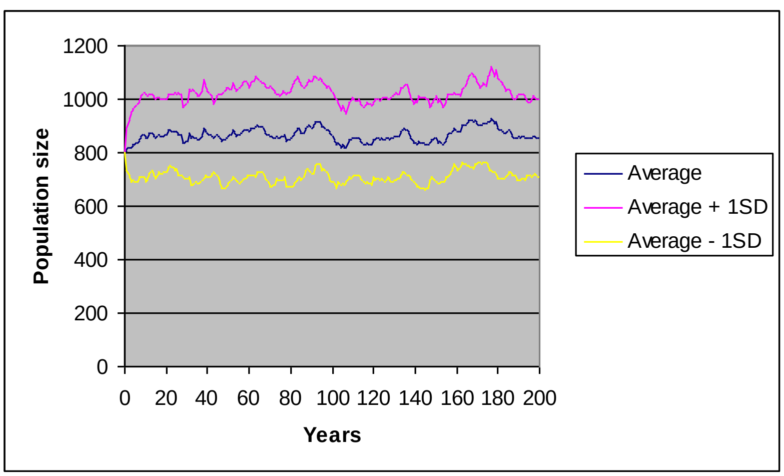


Figure 6.7: The effects of the eradication of all rats and cats on the population size of *A. Barbadensis*

Irrigated gardens scenario

Juvenile and adult mortality is mainly due to visits to urban areas in their search for food during the dry periods (3.6.5). These visits would no longer be necessarily when there are irrigated food patches available in rural areas. Parrots in captivity are known to have high longevities where an average longevity of 40 years is not inconceivable (Brouwer et. al., 2000). Without the threats *A. Barbadensis* is faced with in the urban environment, adult survival is estimated to increase to a longevity of on average 40 years. Additionally, there are no longer fluctuations in survival due to climatic stochasticity. The size of the irrigated gardens was not defined so the actual population size would be limited to the size of these patches. The population size increased to 4500 parrots without restrictions in the size of the gardens (figure 6.8).

However, only a fraction of these birds will be able to reproduce when the number of cavities does not simultaneously increase.

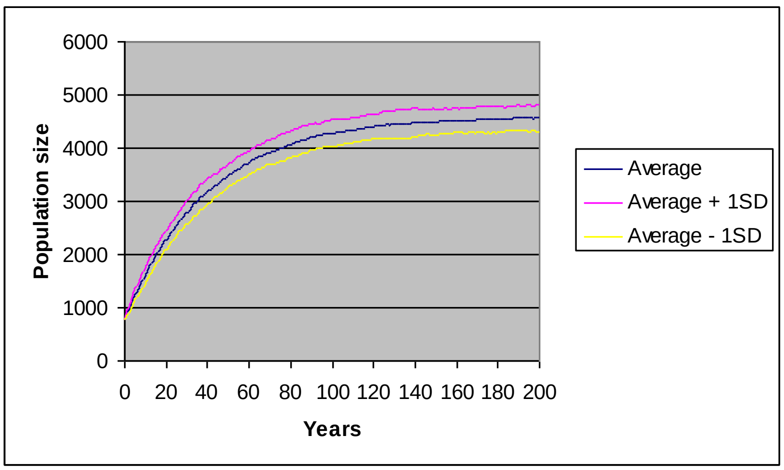


Figure 6.8: The effects of constructing irrigated gardens in rural areas on the population size of *A. Barbadensis*

Tree ringing scenario

This scenario is complementary to the eradication of all goats and donkeys. Natural tree hollow formation can be accelerated by the ringing of trees when they have reached a suitable size as a nesting habitat. Tree cavities are estimated to reach sizes large enough to fit a female parrot after 80 years. The population size increases linearly with increasing nesting habitats (figure 6.9).

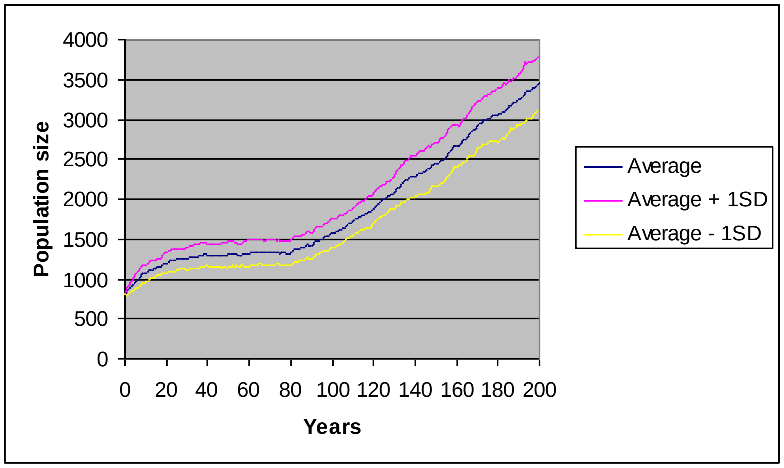


Figure 6.9: The effects of the eradication of goats and donkeys and accelerated cavity formation on the population size of *A. Barbadensis*

Combined conservation scenario

Figure 6.10 reveals the size the population can potentially reach by utilizing all previously discussed conservational measures and without any form of density dependence.

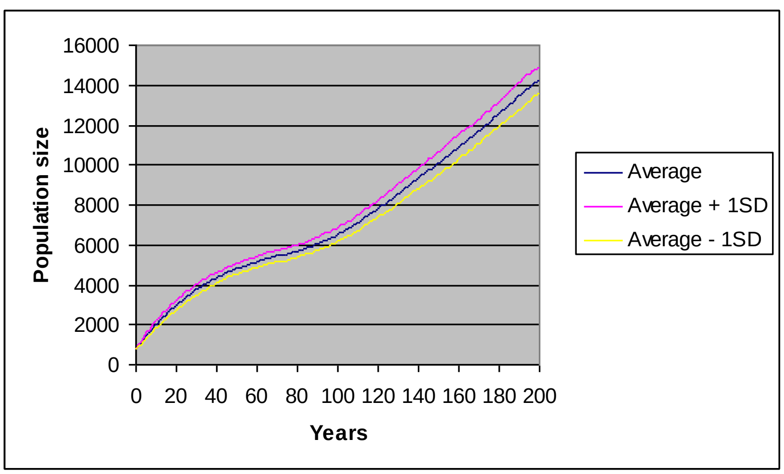


Figure 6.10: The effects of all conservational measures combined on the population size of *A. Barbadensis*

7 Discussion

The discussion is split into five paragraphs. The first two discuss the results of chapter 5 and 6. The third paragraph lists the limitations of this study, followed by a comparison between this study and the available literature. The discussion ends with proposals for future research.

7.1 Sensitivity analyses

The sensitivity analyses regarding the Yellow-shouldered Amazon (*Amazona* Barbadensis) on Bonaire showed no strong sensitivity to variations in chick survival. This is caused by the long average survival of juveniles and adults which provides many future breeding opportunities. The population is very sensitive to juvenile and adult mortality, caused by a slow reproductive biology. Alterations in the number of offspring per female revealed an almost linear relationship to the population size. The population will persist even at low rates of reproduction. These results correspond with the R-k selection theory (chapter 3.4).

A surprising result was the persistence of the population at increasingly high levels of stochasticity in both chick survival and reproduction. The global climate change currently leads to more extremes in climatic variables like temperature and precipitation (www.epa.gov), so an insensitivity to these fluctuations is a fortunate quality.

However, improving survival and reproduction only leads to an increase in the non breeding population when the number of nest sites does not increase. Changing the number of nest sites showed a linear relationship to the population size. Just 140 suitable nesting cavities would lead to almost twice the current population size.

Another interesting result is the sensitivity to long term climate change. Changes in climate affect survival in all life stages as well as reproduction. The sensitivity increases exponentially when the climate conditions improve. This result is probably caused by the changing survival rates of juveniles and adults as the population reacts strongly to increasing survival rates in these categories.

Investigating the reaction of the population to changes in the way the climate affects the population has revealed a high sensitivity to these changes. All comparisons between the climate impact levels were highly significant which emphasizes the need for a better understanding of the impact the climate has on the survival and reproductive parameters of the population.

7.2 Scenarios

One of the positive conclusions that follow from the scenarios is that the parrot population will persist for at least the next 200 years when considering poaching, different urban development scenarios and climate change. However, the consequences

regarding the parrot population are considered separately for each scenario, whereas in reality it will be a combination of these scenarios leading to a more severe population decline or even extinction.
Fortunately do the positive effects of most conservation scenarios on the population size heavily outweigh the negative effects of the previously mentioned scenarios. The scenarios that improved upon the quality of the rural habitat proved to be most effective in increasing the population size over time. This was mainly achieved by further reducing juvenile and adult mortality and increasing the number of tree cavities and thus the breeding population. A conservation plan should concentrate on these subjects as they are more important parameters than reproductivity and chick survival are.
The population size in the combined conservation scenario after 200 years is 14.000 parrots. This extremely large number is not possible on Bonaire when even only considering the required space for nesting activities. Williams (2009) mentioned the occurrence of 4 nests within 200 meters at high density areas. A circle with a diameter of 200 meters equals to 0.0314 km^2, which means 127 nests per square kilometer when the entire habitat is filled with suitable nest sites. Tree nests on Bonaire were primarily distributed between two habitat types (Haematoxylon-Croton and Prosopis-Casearia) (Williams, 2009), which together cover 27.5% of the surface of Bonaire (Freitas et. al., 2005).
27.5% of 288 km^2 equals 79.2 km^2. After a successful goats and donkeys eradication program and consequently allowing the vegetation to fully recover and age over hundreds of years, then there will be a sufficient number of tree cavities for the occurrence of high density nesting in the entire habitat. This will therefore result in 79.2 * 127 = 10.058 nests.
There are additional factors that will further put boundaries on the maximum population size, described in the next paragraph.

7.3 Limitations

The results of this study are mainly intended as exploratory, because certain limitations have caused several assumptions that had to be made. These assumptions generate an uncertainty in the results and have to be tested first before this study can be used for management decisions.

- The field study of Dr. Williams (2009), used to quantify several parameters, spanned almost 3 years. Short term studies are not suitable for population viability analysis because there are large fluctuations over time in environment factors and population parameters (Sanz & Rodriguez-Ferraro, 2006). But as there currently is no long term study available, the study of Dr. S. Williams had to suffice and was still preferred over using the results of a long term study about the survival and reproduction of *A. Barbadensis* on a different island.

- The effect of climatic stochasticity on *A. Barbadensis* is unknown and the ranges in reproduction and survival were therefore assumed.
- The amount of predation by rats and cats on nestlings on Bonaire is not known. Instead the predation rate of Rodriguez et. al. (2004) was used. However, this rate is based on the situation on Margarita, an island with different predators.
- Juvenile and adult survival ranges were used from the *A. Barbadensis* population viability analysis of Rodriguez et. al. (2004) on Margarita island. These ranges are not based on an actual field study as there has not been conducted any. Juvenile and adult survival in the wild is an understudied topic in almost all parrot species.
  Dr. S. Williams estimated an average adult survival of 40 years (pers. comm.) which is substantially higher than the aforementioned survival ranges. Field studies are needed to provide definitive answers on this matter.
- Density dependence occurs in many variations in the wild, but is currently limited to the number of nest sites in the model. For example food availability will become a density dependent factor in several conservation scenarios when the population size increases to (much) more than double the current population size. This also applies for human toleration as thousands of *A. Barbadensis* would likely be considered as a pest during dry periods. Another example of density dependence is a relative increase in poaching when the conditions for reproduction are improved. Thus the reality is much more complex than the model currently would let us believe. This should of course come as no surprise.

7.4 Comparisons to literature

Only one population viability analysis of *A. Barbadensis* was available in the English literature. Rodríguez et. al. (2004) used PVA to estimate the extinction risk and the change in population size over time of *A. Barbadensis* on Margarita Island and La Blanquilla. Additionally they quantified the maximum allowable poaching intensity (MAPI). Their analysis resulted in a MAPI of 60% which is very close to the MAPI of 50% for Bonaire in this study. The slight difference can be caused by the different programs used, or the different parameters found between the islands.
Just like the study presented in this thesis, are the parrot populations on the Venezuelan islands very sensitive to juvenile and adult survival. The populations both had gone extinct after 100 years when annual juvenile and adult survival was set at ≤ 85%.
The model presented here is slightly less sensitive as the population persists after 100 years when annual juvenile and adult survival ranges between 73% and 87%.

7.5 Future research

Future research should concentrate on testing the aforementioned assumptions that have been made during this study. Secondly, the modeling program METAPHOR could be more adjusted to this specific species. Currently the model can only count the population size annually which has resulted in different life stages in the model compared to the life stages described in the literature (chick, juvenile and adult versus nestling, fledgling and adult). This will become important when there are accurate survival rates available for nestlings, fledglings and adults. Finally, the input tables in the appendices can be used to generate more realistic scenarios by combining the effects of separate scenarios as they are described in this thesis.

8 Recommendations

The analyses in the previous chapters were mainly conducted for exploratory purposes; to gain insights in the population dynamics of the Yellow-shouldered Amazon (*Amazona Barbadensis*) on Bonaire. However, the results from the sensitivity analyses and scenarios do lead directly to several recommendations regarding the sustainable management of the species (when assuming the assumptions, listed in paragraph 7.3, have been tested and were correct).

- Poaching is currently not a threat to the persistence of the parrot population, but the intensity of poaching depends on several factors (e.g. legislation, economy, demands) and can therefore increase over time. Poaching pressure may however never exceed the 50% threshold as extinction is likely at higher rates. A certain degree of supervision on poaching activities is therefore recommended.
- When poaching rates do reach alarmingly high values, then there are several options to protect the nests. Examples are a public awareness campaign, active nest guarding and other alternatives further described in chapter 3.7.2.. An awareness campaign should always be a part of a conservation program as it is the only true sustainable strategy.
- A decline in the number of tree cavities caused by the chick extraction methods of the poachers, is also very harmful to the parrot population. Recommended is that these nests get repaired and moved in their entirety to safer, i.e. less visible or harder to reach, locations.
- The introduced cats and rats should be monitored on population size, because a high predation pressure on eggs and nestlings is especially harmful for a species that is nest site limited and thus already has a low growth rate. This is made worse by the slow reproductive biology of parrots.
- Juvenile and adult survival appeared to be even more important than the survival of the chicks, which was expected as parrots are a K selected species (chapter 3.4). Preventing juvenile and adult mortality therefore has a high priority. This can be achieved by raising awareness among landowners to minimalize conflicts. Another method is adjusting windows to make them less transparent (i.e. place them under an angle) which prevents birds from crashing against the windows. Of course the best option would be to prevent parrots from visiting urban areas altogether by improving the quality of the habitat in the rural areas. This can be achieved by the eradication of all goats and donkeys or by irrigating rural areas.
- All survival enhancing measures only increases the size of the non breeding population as long as the parrots remain nest site limited. The eradication of goats and donkeys is highly recommended to allow regeneration of the vegetation which will result in an increase in tree cavities over time. Several studies showed that natural hollow formation is a slow process. An eradication

program is costly so support might be low when the benefits are not readily apparent in the short term. Tree ringing could serve as a solution as it accelerates the deterioration of the trees.

- The complementary urban development scenario (ROB2), designed by the government, is because of the short lifespan not a serious risk to the viability of the parrot population, but the first scenario is recommended as a development strategy for the long term as it has a smaller impact on the nesting and roosting sites distributed over the island.
- A reintroduction on Curacao and Aruba is recommended to further enhance the species chance of survival and a reintroduction would further restore the ecosystem as *A. Barbadensis* once was a native bird on these islands.
- It is recommended to continue the annual population count as a low cost conservation strategy to identify a decrease in the population size in an early stage. Counter measures can then be taken accordingly.

Conclusions

The main threats the Yellow-shouldered Amazon (*Amazona Barbadensis*) faces on Bonaire are:

- Poaching: The extraction of nestlings for the illegal pet trade and the associated destruction of the nesting habitat;
- Predation: The predation of nestlings by rats and cats;
- Habitat degradation: The degraded state of the vegetation, caused by feral goats and donkeys, leading to food shortage and nest site limitation;
- Urban development: The loss of breeding sites caused by urban development;

The main opportunities that aid in the persistence of *A. Barbadensis* on Bonaire are:

- Public awareness: Creating awareness of the endangered state of the parrot amongst villagers, land owners and decision makers;
- Poaching reducing methods: When poaching reaches a rate of 50% or higher;
- Nest repair: Reparation of damaged nest by poaching and the transfer to a safer location;
- Eradication of all exotic mammals: Eradication of rats, cats, goats and donkeys will lead to improved survival rates in all life stages and will improve reproduction and increase the number of nest sites;
- Reintroduction: The reintroduction of *A. Barbadensis* on the islands Curacao and Aruba as the species is native to these islands;

The sensitivity analyses revealed the importance of juvenile and adult survival for a viable population and the need for a better understanding of the effect the climate has on the population parameters.

The factors that currently threaten the *A. Barbadensis* population on Bonaire will not lead to extinction within the next 200 years when the threats are considered individually, but the combined effects on the population size most likely does lead to extinction. The conservation scenarios led to viable populations of up to many thousands of parrots. The measures responsible for the most optimistic results in population size were improving the natural habitat of *A. Barbadensis* which reduced dangerous visits to urban areas and consequently increased juvenile and adult survival. Another important measure was the eradication of goats and donkeys which increased both the survival in all life stages and the number of nest sites over times leading to a larger breeding population. These measures led to a virtually endless increase in population size. However, future research should focus on the density dependant factors that put boundaries on the growth rate.

A. Barbadensis on Bonaire can be considered as viable under current circumstances, based on the results of this study. Annual monitoring of the population is important, as several environmental factors can drastically change the population size. Measures can then be taking promptly and accordingly.

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Personal Communication

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Dr. Verboom-Vasiljev, J. An expert in ecology, currently leading the team Ecological models and monitoring at Alterra.

Websites

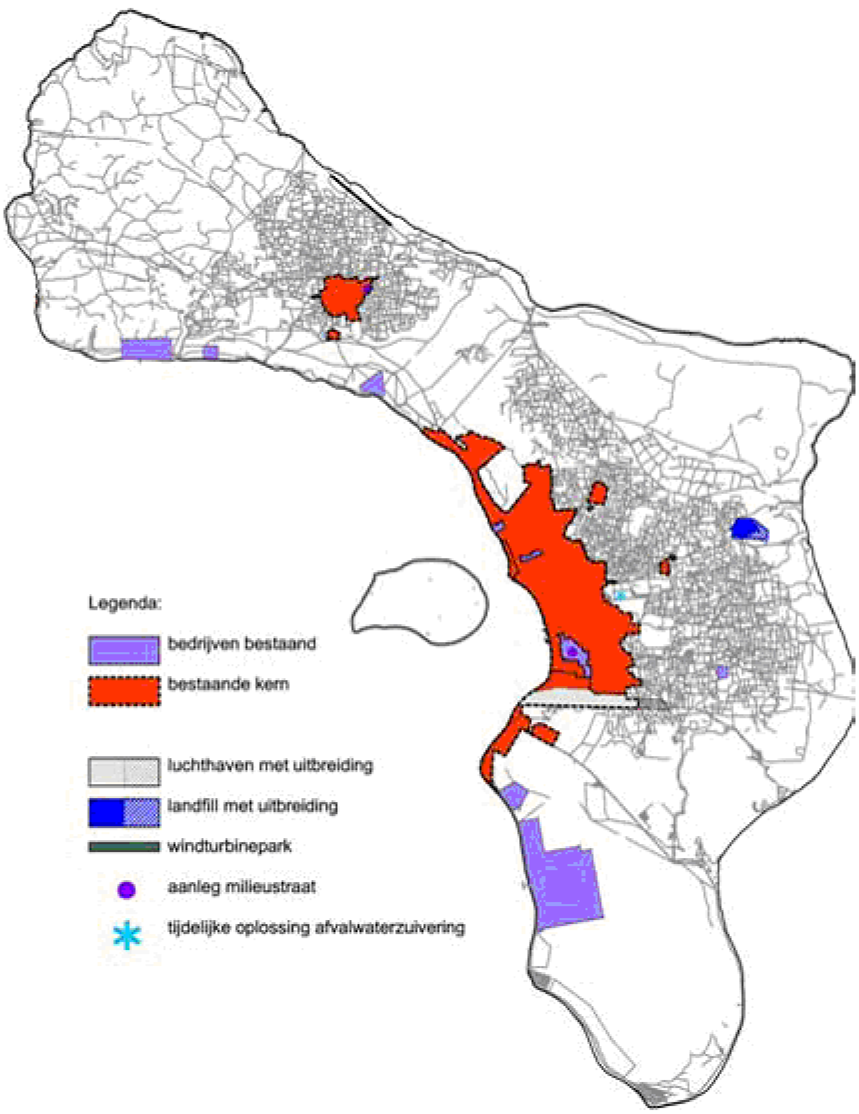
- URL http://www.banboneirubek.com/content/aantal-inwoners-op-bonaire-stijgt-naar-15980, number of inhabitants on Bonaire, consulted on 05-12-2011
- URL http://www.bonairenet.com/infonl.htm, general information of Bonaire, consulted on 05-12-2011
- URL http://www.echobonaire.org/echo/goals.html, conservational goals on Bonaire, consulted on 13-12-2011
- URL http://www.echobonaire.org/Echo/Achievements.html, achievements on Bonaire by Echo Bonaire, consulted on 14-12-2011
- URL http://www.ecotourism.org/site/c.orLQKXPCLmF/b.4835303/k.BEB9/What_is_Ecotourism__The_International_Ecotourism_Society.htm, definition ecotourism, consulted on 13-12-2011
- URL http://epa.gov/climatechange/effects/extreme.html, global effect climate change, consulted on 06-01-2012
- URL http://www.gemeentebonaire.com/overgangsakkoord12feb.htm, transition to special municipality, consulted on 05-12-2011
- URL http://www.iucnredlist.org/technical-documents/categories-and-criteria/2001-categories-criteria, IUCN, 2001, IUCN Red list categories and criteria version 3.1, consulted on 20-11-2011

- URL http://www.pmel.noaa.gov/tao/elnino/el-nino-story.html, The El Niño oscillation, consulted on 13-12-2011
- URL http://www.planetware.com/map/bonaire-map-nan-nan141.htm, Map of Bonaire, consulted on 05-12-2011
- URL http://publications.europa.eu/official/index_en.htm, European legislation on trade, consulted on 11-12-2011
- URL http://iucnredlist.org, International Union for Conservation of Nature and Natural Resources, consulted on 06-12-2011

APPENDICES

Appendix 1: Reference situation (map)

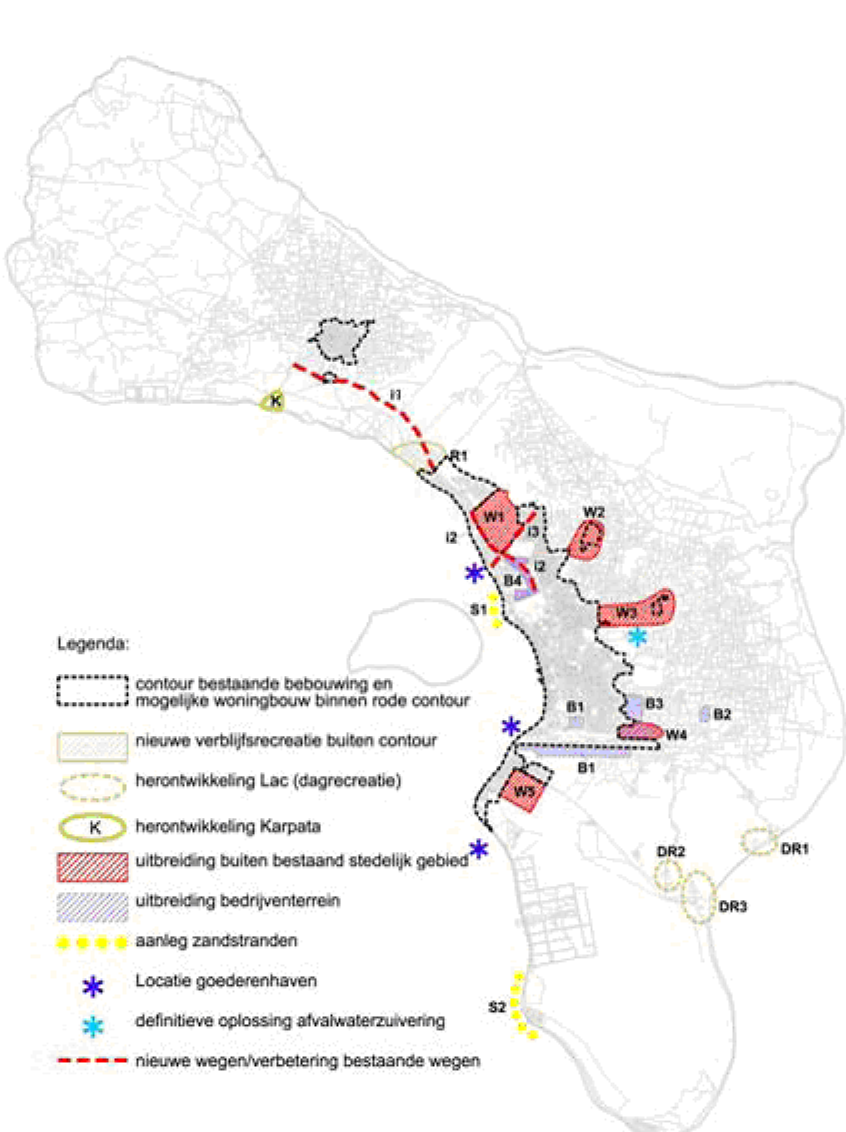
The figure below displays the current situation on Bonaire, regarding the urban areas.



(Lammens, 2010)

Appendix 2: Map of the ROB 1 scenario

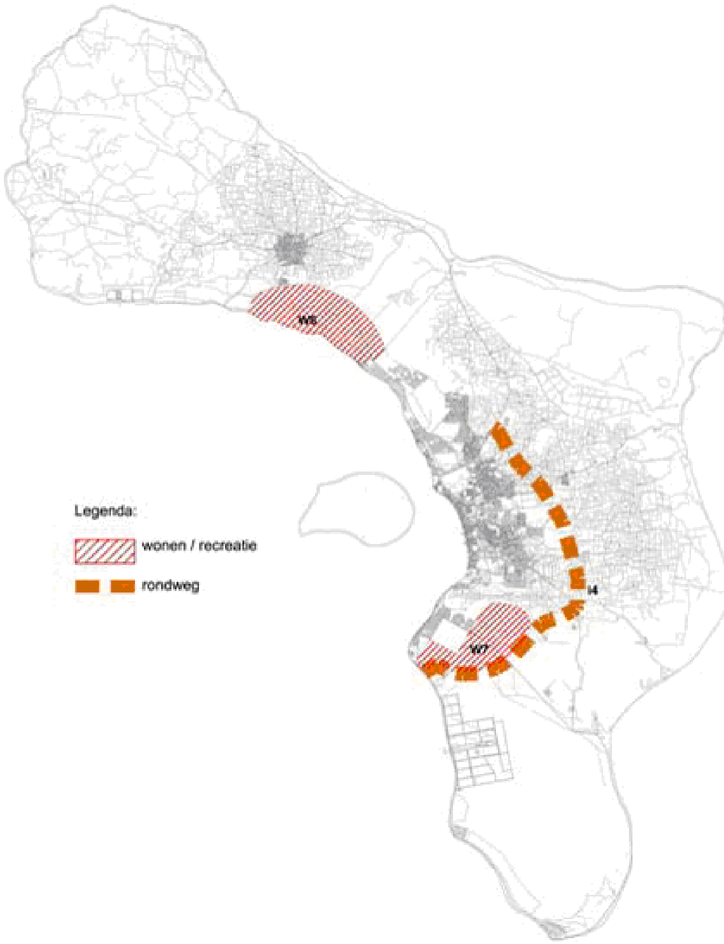
This map reveals the areas of interest for urban development in the first scenario.



(Lammens, 2010)

Appendix 3: Map of the ROB 2 scenario

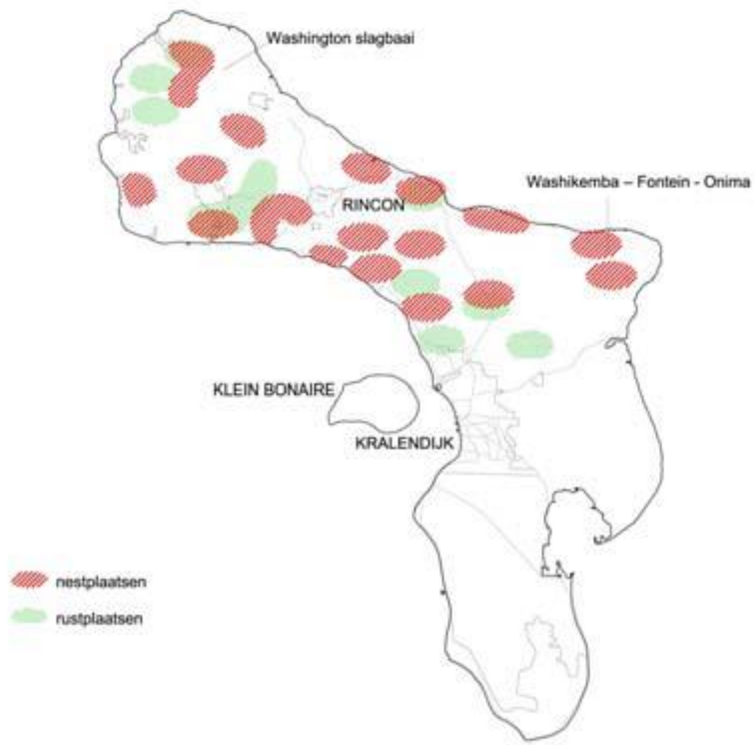
This figure shows the urban development considered as complementary to ROB 1.



(Lammens, 2010)

Appendix 4: Map of the resting and roosting sites

The nesting and roosting sites that are currently known on Bonaire are displayed on the map below.



(Lammens, 2010)

Appendix 5: METAPHOR input tables for the sensitivity analyses

This appendix includes all the input data for METAPHOR for anyone who wishes to replicate the executed analyses.

Description of the table contents

- Q = climate parameter. This variable can vary between 0 and 1 and the number is directly related to survival and reproduction.
- P chicks at Q0 = The survival probability of chicks when climate is at 0 (worst climate conditions)
- P chicks at Q1 = The survival probability of chicks when climate is at 1 (optimal climate conditions)
- Chick S.D. = The standard deviation belonging to chick survival changed proportionally to changes in the survival rates of the chicks
- P J&A at Q0 = The survival probability of juveniles and adults when climate is at 0
- P J&A at Q1 = The survival probability of juveniles and adults when climate is at 1
- Fem. Repr. at Q0 = Female reproduction (number of chicks) when climate is at 0
- Fem. Repr. at Q1 = Female reproduction when climate is at 1
- Fem. Repr. S.D. = The standard deviation belonging to the female reproduction changed proportionally to changes in the female reproduction

Sensitivity to poaching

Poaching intensity	P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.0	0.6	0.9	0.17	0.8	0.95	1.46	2.18	0.69
0.1	0.5	0.8	0.14	0.8	0.95	1.46	2.18	0.69
0.2	0.4	0.7	0.12	0.8	0.95	1.46	2.18	0.69
0.3	0.3	0.6	0.10	0.8	0.95	1.46	2.18	0.69
0.4	0.2	0.5	0.08	0.8	0.95	1.46	2.18	0.69
0.5	0.1	0.4	0.06	0.8	0.95	1.46	2.18	0.69
0.6	0.0	0.3	0.03	0.8	0.95	1.46	2.18	0.69
0.7	0.0	0.2	0.02	0.8	0.95	1.46	2.18	0.69
0.8	0.0	0.1	0.01	0.8	0.95	1.46	2.18	0.69

Number of nests: 70
Population size: 800
Climate: Random

Sensitivity to predation

Predation intensity	P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.0	0.56	0.86	0.16	0.8	0.95	1.46	2.18	0.69
0.1	0.46	0.76	0.13	0.8	0.95	1.46	2.18	0.69
0.2	0.36	0.66	0.11	0.8	0.95	1.46	2.18	0.69

Number of nests: 70
Population size: 800
Climate: Random

Sensitivity to chick survival

P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.08	0.12	0.02	0.8	0.95	1.46	2.18	0.69
0.15	0.25	0.04	0.8	0.95	1.46	2.18	0.69
0.23	0.37	0.07	0.8	0.95	1.46	2.18	0.69
0.30	0.50	0.09	0.8	0.95	1.46	2.18	0.69
0.45	0.75	0.13	0.8	0.95	1.46	2.18	0.69
0.53	0.87	0.15	0.8	0.95	1.46	2.18	0.69
0.60	1.00	0.18	0.8	0.95	1.46	2.18	0.69
0.68	1.00	0.18	0.8	0.95	1.46	2.18	0.69
0.75	1.00	0.19	0.8	0.95	1.46	2.18	0.69

Number of nests: 70
Population size: 800
Climate: Random

The survival range of the chicks changes proportionally in size:

(0,46+0,76)/2 = 0,61
0,61/0,46 = 1,33 (relationship between lower range value and the average value)
0,76/0,61 = 1,25 (relationship between the higher range value and the average value)

I used survival averages at intervals of 0,1, thus for example the range for P=0,1 would be:
For Q0 when P=0,1 -> 0,1/1,33 = 0,08
For Q1 when P=0,1 -> 0,1*1,25 = 0,12

Sensitivity to stochastic intensity of chick survival

P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.46	0.76	0.0	0.8	0.95	1.46	2.18	0.69
0.46	0.76	0.13	0.8	0.95	1.46	2.18	0.69
0.46	0.76	0.26	0.8	0.95	1.46	2.18	0.69
0.46	0.76	0.39	0.8	0.95	1.46	2.18	0.69
0.46	0.76	0.52	0.8	0.95	1.46	2.18	0.69

Number of nests: 70
Population size: 800
Climate: Random

Sensitivity to juvenile and adult survival

P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.46	0.76	0.13	0.37	0.43	1.46	2.18	0.69
0.46	0.76	0.13	0.46	0.54	1.46	2.18	0.69
0.46	0.76	0.13	0.55	0.65	1.46	2.18	0.69
0.46	0.76	0.13	0.64	0.76	1.46	2.18	0.69
0.46	0.76	0.13	0.73	0.87	1.46	2.18	0.69
0.46	0.76	0.13	0.82	0.98	1.46	2.18	0.69
0.46	0.76	0.13	0.87	1.00	1.46	2.18	0.69
0.46	0.76	0.13	0.89	1.00	1.46	2.18	0.69

Number of nests: 70
Population size: 800
Climate: Random

Sensitivity to female reproduction

P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.46	0.76	0.13	0.80	0.95	0.4	0.6	0.19
0.46	0.76	0.13	0.80	0.95	0.8	1.2	0.38
0.46	0.76	0.13	0.80	0.95	1.2	1.8	0.57
0.46	0.76	0.13	0.80	0.95	1.6	2.4	0.76
0.46	0.76	0.13	0.80	0.95	2.0	3.0	0.95
0.46	0.76	0.13	0.80	0.95	2.4	3.6	1.13

Number of nests: 70
Population size: 800
Climate: Random

The standard deviation of female reproduction changes proportionally to the reproduction.

Sensitivity to stochastic intensity of female reproduction

P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.46	0.76	0.13	0.80	0.95	1.46	2.18	0.0
0.46	0.76	0.13	0.80	0.95	1.46	2.18	0.69
0.46	0.76	0.13	0.80	0.95	1.46	2.18	1.38
0.46	0.76	0.13	0.80	0.95	1.46	2.18	2.07

Number of nests: 70
Population size: 800
Climate: Random

Sensitivity to the number of available nests

P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.46	0.76	0.13	0.80	0.95	1.46	2.18	0.69

Number of nests: 35 / 40 / 50 / 60 / 70 / 80 / 90 / 100 / 110 / 120 / 130 / 140
Population size: 800
Climate: Random

Sensitivity to climate:

P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0.46	0.76	0.13	0.80	0.95	1.46	2.18	0.69

Number of nests: 70
Population size: 800
Climate: 0.0 / 0.1 / 0.2 / 0.3 / 0.4 / 0.5 / 0.6 / 0.7 / 0.8 / 0.9 / 1.0

Sensitivity to climate impact

Climate Impact Level	Failed nests	P chicks at Q 0	P chicks at Q1	Chick S.D.	P J&A at Q0	P J&A at Q1	Fem. Repr. at Q0	Fem. Repr. at Q1	Fem. Repr. S.D.
0	10	0.76	0.76	0.17	0.95	0.95	2.18	2.18	0.82
1	16.67	0.66	0.76	0.16	0.90	0.95	1.94	2.18	0.78
2	23.33	0.56	0.76	0.15	0.85	0.95	1.70	2.18	0.73
3	30	0.46	0.76	0.13	0.80	0.95	1.46	2.18	0.69
4	36.67	0.36	0.76	0.12	0.75	0.95	1.21	2.18	0.64
5	43.33	0.26	0.76	0.11	0.70	0.95	0.97	2.18	0.60
6	50	0.16	0.76	0.10	0.65	0.95	0.73	2.18	0.55
7	56.67	0.06	0.76	0.09	0.60	0.95	0.49	2.18	0.50

Number of nests: 70
Population size: 800
Climate: Random

All standard deviations are proportional to the values they belong to.

For example:
Female reproduction S.D. at climate impact level 1
16.67 failed nests =
70 – 16.67 = 53.33 nests
53.33/70 = 0.76
0.76*2.55 = 1.94
((1.94+2.18)/2)*0.378 = 0.78

Appendix 6: Statistical significance of the sensitivity analyses

All comparisons between the averages of different groups are displayed in the following tables. The population size was normally distributed for every analysis and thus the parametric test One-way ANOVA post hoc LSD was used for every analysis. Results were significant when p < 0,05.

Poaching intensity:

Poaching	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
0.0	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.1	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.2	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000
0.3	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000
0.4	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000
0.5	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000
0.6	0.000	0.000	0.000	0.000	0.000	0.000	X	0.005	0.004
0.7	0.000	0.000	0.000	0.000	0.000	0.000	0.005	X	0.924
0.8	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.924	X

Predation:

Predation	0.0	0.1	0.2
0.0	X	0.000	0.000
0.1	0.000	X	0.000
0.2	0.000	0.000	X

Chick survival:

Chick Sur.	0.08-0.12	0.15-0.25	0.23-0.37	0.30-0.50	0.38-0.62	0.45-0.75	0.53-0.87	0.60-1.00	0.68-1.00	0.75-1.00
0.08-0.12	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.15-0.25	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.23-0.37	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.30-0.50	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000
0.38-0.62	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000
0.45-0.75	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000
0.53-0.87	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000
0.60-1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.021	0.001
0.68-1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021	X	0.296
0.75-1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.296	X

Standard deviation of chick survival:

Chick SD	0.00	0.13	0.26	0.39	0.52
0.00	X	0.720	0.700	0.245	0.070
0.13	0.720	X	0.458	0.128	0.030
0.26	0.700	0.458	X	0.436	0.153
0.39	0.245	0.128	0.436	X	0.516
0.52	0.070	0.03	0.153	0.516	X

Juvenile and adult survival:

JAsur	0.37-0.43	0.46-0.54	0.55-0.65	0.64-0.76	0.73-0.87	0.82-0.98	0.87-1.00	0.89-1.00
0.37-0.43	X	1.000	1.000	0.877	0.000	0.000	0.000	0.000
0.46-0.54	1.000	X	1.000	0.877	0.000	0.000	0.000	0.000
0.55-0.65	1.000	1.000	X	0.877	0.000	0.000	0.000	0.000
0.64-0.76	0.877	0.877	0.877	X	0.000	0.000	0.000	0.000
0.73-0.87	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000
0.82-0.98	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000
0.87-1.00	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000
0.89-1.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X

Female reproduction:

Fem rep	0.4-0.6	0.8-1.2	1.2-1.8	1.6-2.4	2.0-3.0	2.4-3.6
0.4-0.6	X	0.000	0.000	0.000	0.000	0.000
0.8-1.2	0.000	X	0.000	0.000	0.000	0.000
1.2-1.8	0.000	0.000	X	0.000	0.000	0.000
1.6-2.4	0.000	0.000	0.000	X	0.000	0.000
2.0-3.0	0.000	0.000	0.000	0.000	X	0.000
2.4-3.6	0.000	0.000	0.000	0.000	0.000	X

Standard deviation of reproduction:

Repro SD	0.00	0.69	1.38	2.07
0.00	X	0.889	0.495	0.003
0.69	0.889	X	0.588	0.004
1.38	0.495	0.588	X	0.019
2.07	0.003	0.004	0.019	X

Number of nests:

N nest	35	40	50	60	70	80	90	100	110	120	130	140
35	X	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	0.028	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
70	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000
80	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000
90	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000
100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000
110	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000
120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000
130	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000
140	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X

Climate:

Climate	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.1	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.2	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.3	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.4	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000
0.5	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000
0.6	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000
0.7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000
0.8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000
0.9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000
1.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X

Climate impact:

Climate impact	0	1	2	3	4	5	6	7
0	X	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	X	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	X	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	X	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	X	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	X	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	X	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	X

Appendix 7: METAPHOR input table for the different scenarios

Scenario	Chick survival	Chick S.D.	Juvenile. & Adult survival	Female reprod.	Female repr.S.D.	Number of nests	Climate
Current	0.46-0.76	0.13	0.80-0.95	1.46-2.18	0.69	70	R
Poaching	0.46-0.76	0.13	0.80-0.95	1.46-2.18	0.69	70-7%/yr	R
Dry	0.46-0.76	0.13	0.80-0.95	1.46-2.18	0.69	70	0.0-0.5
Wet	0.46-0.76	0.13	0.80-0.95	1.46-2.18	0.69	70	0.5-1.0
ROB 1	0.46-0.76	0.13	0.80-0.95	1.46-2.18	0.69	70-0.025/yr	R
ROB 2	0.46-0.76	0.13	0.80-0.95	1.46-2.18	0.69	70-0.270/yr	R
No goats	0.66-0.76	0.16	0.90-0.95	1.81-2.18	0.75	70+1/yr after 140yrs	
No poaching	0.60-0.90	0.17	0.80-0.95	1.46-2.18	0.69	70	R
No rats & cats	0.56-0.86	0.16	0.80-0.95	1.81-2.55	0.82	70	R
Irrig. Gardens	0.76-0.76	0.17	0.975-0.975	2.18-2.18	0.82	70	R
Tree ringing	0.66-0.76	0.16	0.90-0.95	1.81-2.18	0.75	70+1/yr after 75 yrs	R
Conservation	0.975-0.975	0.21	0.975-0.975	2.55-2.55	0.96	70+1/yr after 75 yrs	R