The cheetah and their cubs

A literature study about the offspring mortality rate of cheetahs before emergence

Bachelor thesis

Eline Kemper
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Preface

After studying for four years at Aeres University of Applied Sciences, I will conclude my time in Dronten with this bachelor thesis. I wrote this bachelor thesis during my final months of my studies 'Animal Health & Management'. I have been working on this from April 2022 till June 2022.

From September till February 2022 I followed the minor 'Wildlife Management'. I have always had a predilection for wildlife, with a special interest in cheetahs, and during this minor I got the opportunity to learn more about wildlife and the struggles they face. This motivated me to write my bachelor thesis on this topic. Maybe this research could be used by conservationists or researchers who are trying to find ways to help with cheetah conservation.

Without my tutors Ms. M. Bos, Ms. L. Spit and Ms. A. Landsman, the writing of this bachelor thesis would not have been possible. That is why I would like to thank them for their guidance, help and feedback during this last phase of my studies. I would also like to thank my parents for the support they have given me during this process.

I hope you enjoy reading this bachelor thesis.

Eline Kemper
Leeuwarden, June 2022

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Glossary

Altricial	An animal that is born in an undeveloped state; they are helpless at birth, so they need care and feeding.
Bottleneck	An event that causes a drastic decrease in the size of a population, which limits the genetic diversity of the species.
Historic range	Geographical areas that a species has occupied in the past.
Home range	The geographical area in which an animal lives and moves.
Kleptoparasite	An animal that steals food that was caught or collected by another animal. In other words: an animal that robs other animals of their resources.
Locomotive competency	The ability of an animal to move their body from one place to another, like: walking, running, jumping, climbing and crawling.
Promiscuous	Having multiple different sexual partners, so not restricted to one or a few sexual partners.
Protected area	An area that is protected by law or other effective means, because it has a cultural, natural or ecological importance. The aim of this protection is the conservation of nature.

Abstract

The global population of cheetahs is declining, which is a threat to the health of their ecosystems and biodiversity. Cheetahs are listed as 'Vulnerable' on the IUCN Red List, but some conservation scientists want them to be up listed from to 'Endangered'. The decline in cheetah populations is a result of several causes. One of them is their high offspring mortality. The aim was to identify the main causes of why so many cheetah cubs die before emergence, to see how conservationists could make sure that cheetah cubs survive until emergence, so they have more chance of surviving until their adolescence. This protection would be needed to contribute to the reduction of the decline in cheetah populations, what would also help with increasing biodiversity. The main question is:

'Why do cheetahs (Acinonyx jubatus) have a high offspring mortality rate before emergence from the lair?'

To answer this main question, a literature research has been conducted. The main results of the literature research are:

- Predation is the major cause of death for cubs until emergence.
- Predation is less likely outside protected areas.
- There are two human threats for cubs: residents and illegal trade.
- Shortages of food and/or water reduce the survival chances of cubs until emergence.
- Climate change may reduce the survival chances of cubs until emergence.
- In habitats with denser vegetation, cubs have more chance of survival until emergence.
- The nurturing behavior of mothers is important for the survival of cubs until emergence for five reasons.

The conclusion therefore is that the following causes explain the high offspring mortality rate before emergence: predation, kills by residents, illegal trade, shortages of food and/or water and climate change. Based on the conclusions, it is recommended to prevent or reverse thorn bush encroachment, to preserve woodlands, to educate residents and to employ rangers to patrol outside protected areas.

Some points of discussion are that some information was not double checked to see if it is also reflected in other sources and that some topics were not covered or not extensively covered in this thesis. Follow-up research may be about what causes mortality in cheetah cubs *after* emergence, about what causes stress in wild cheetahs that results in a pause in reproductivity or about how many cheetah mothers die because of predation and what that means for the population numbers of cheetahs.

Samenvatting

Wereldwijd neemt het aantal jachtluipaarden af, dit vormt een gevaar voor de gezondheid van hun ecosystemen en voor biodiversiteit. Jachtluipaarden staan geclassificeerd als 'Kwetsbaar' op de IUCN Rode Lijst, maar er zijn natuurwetenschappers die willen dat ze worden opgeschaald naar 'Bedreigd'. De afname van het aantal jachtluipaarden kent verschillende oorzaken. Eén daarvan is het hoge sterftecijfer van nakomelingen. Het doel was om de belangrijkste oorzaken te achterhalen van de hoge sterfte onder jachtluipaardwelpen voordat ze hun schuilplaats verlaten. Die kennis kan leiden tot aanbevelingen voor natuurbeschermers, hoe zij ervoor kunnen zorgen dat jachtluipaardwelpen deze periode overleven, zodat ze meer kans hebben om te overleven tot hun adolescentie. Deze bescherming zou nodig zijn om de afname van jachtluipaard populaties te reduceren, wat ook zou helpen bij het vergroten van de biodiversiteit. De hoofdvraag is:

'Waarom hebben jachtluipaarden (Acinonyx jubatus) een hoog sterftecijfer van nakomelingen voordat deze hun schuilplaats verlaten?'

Om deze hoofdvraag te beantwoorden is er literatuuronderzoek gedaan. De belangrijkste resultaten van het literatuuronderzoek zijn als volgt:

- Predatie is de belangrijkste doodsoorzaak voor welpen totdat zij hun schuilplaats verlaten.
- Predatie is minder waarschijnlijk buiten beschermde gebieden.
- Er zijn twee menselijke bedreigingen voor welpen: inwoners en illegale handel.
- Onvoldoende beschikbaarheid van voedsel en/of water verkleint de overlevingskansen van welpen totdat zij hun schuilplaats verlaten.
- Klimaatverandering kan de overlevingskansen van welpen totdat zij hun schuilplaats verlaten verkleinen.
- In habitatten met dichtere vegetatie hebben welpen meer kans om te overleven totdat zij hun schuilplaats verlaten.
- Verzorgend gedrag van moeders is voor vijf redenen belangrijk voor het overleven van welpen totdat zij hun schuilplaats verlaten.

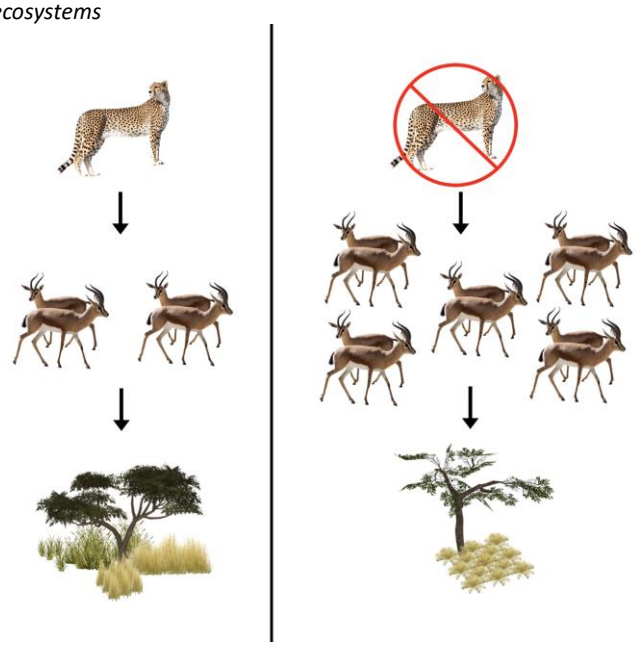
De conclusie is dat de volgende oorzaken het hoge sterftecijfer van nakomelingen voordat ze hun schuilplaats verlaten verklaren: predatie, het doden door inwoners, illegale handel, onvoldoende beschikbaarheid van voedsel of water en klimaatverandering. Op basis van de resultaten wordt het aanbevolen om aantasting op natuurlijke vegetatie door doornstruiken te voorkomen of op te lossen, bossen te behouden, inwoners te onderwijzen en 'rangers' in dienst te nemen om buiten beschermde gebieden te patrouilleren.

Discussiepunten zijn dat sommige informatie niet dubbel gecontroleerd is, om te zien of andere bronnen deze informatie ook weergeven en dat sommige onderwerpen niet of niet uitgebreid aan bod zijn gekomen in dit afstudeerwerkstuk. Vervolgonderzoek kan gaan over wat sterfte bij welpen veroorzaakt na het verlaten van hun schuilplaats, over welke oorzaken van stress bij wilde jachtluipaarden leidt tot een pauze in de reproductiviteit of over hoeveel jachtluipaardmoeders sterven door predatie en wat dat betekent voor de populatieaantallen.

1. Introduction

The world is currently facing a biodiversity crisis; extinction rates have increased in the past century. Currently, one million species are facing extinction (Díaz, S., Settele, J. & Brondízio, E, 2019). As to large carnivores, 64% of this group of species are threatened with extinction and 80% has a declining population trend (Wolf & Ripple, 2018). Habitat loss and fragmentation, invasive species, diseases, climate change, human-wildlife conflict and prey depletion are threats to large carnivores (MacDonald, 2016). Felines (*Felidae*) is a group of carnivores and consists out of 38 species (Kitchener et al., 2017). 14 Of these species are listed as 'Least Concern' on the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, 13 are listed as 'Vulnerable', five as 'Endangered' and six as 'Near Threatened'. The population numbers of only seven of these 38 species are stable or rising, the others are decreasing (IUCN Red List, n.d.). The criteria of the IUCN Red List are a tool to identify the extinction risk of species and it enables the prioritization of species facing the biggest threat. For instance, it is used to revise the annexes of international agreements like the Convention on International Trade in Endangered Species (CITES) (IUCN Red List, n.d.). The cheetah (*Acinonyx jubatus)* is a large carnivore and is also part of the family *Felidae*. The cheetah is considered Vulnerable in the IUCN Red List (IUCN Red List, n.d.). However, there is some discussion about this classification. Conservation scientists revealed significant population declines in a study in 2016 and they say that the cheetah is closer to extinction than the IUCN Red List suggests. They want the cheetah to be up listed from Vulnerable to Endangered (Durant, et al., 2016). Currently, there are approximately 7100 cheetahs left in the wild and they lost 91% of their historic range due to habitat loss and fragmentation. This decline in habitat results in an increase in the abundance of other large predators, like lions or hyenas, in protected areas. Since cheetahs are built for their speed and not their strength, they have a disadvantage with protecting their territories or offspring. Hence, cheetahs mainly live outside protected areas, where there is less other large predators. However, this brings competition with farmers forth. Cheetahs are being killed, because farmers see them as a threat to their livestock (Tommasi, et al., 2021). The decline in cheetah populations are a threat to the health of their ecosystems, because top predators maintain the balance in ecosystems. Top predators limit the number of herbivores, what reduces the pressure that herbivores place on plants (Miller et al., 2001). Figure 1 displays this for the cheetah.

Figure 1.
Impact of top predators on ecosystems



Note. From The City University of New York, 2019, modified by E. Kemper.

So, cheetahs have a direct and indirect effect on herbivores. Directly by predatory and indirectly by changing the behavior of them; prey choose different habitats and start to avoid certain places. These places can then regenerate, what creates new habitats and attracts other animals. This increases biodiversity, which contributes to a healthy ecosystem (Agnos, C. & Agnos D., 2019).

The life expectancy of the cheetah is approximately 12 years in the wild (Zagata, 2019). Male cheetahs can live alone, also known as 'solitary', but they usually form coalitions. These coalitions consist out of one or two other male cheetahs, usually their littermates (National Geographic, n.d.). Male cheetahs are territorial, they will mark the boundaries of their territory with urine and faeces. Their territory usually spans from 13 to 26 square kilometers, but can extend up to 130 square kilometers (Means, 2022). They position their territories where females are bound to pass, so they have reproductive opportunities. Female cheetahs are solitary animals, except when they are raising their cubs. Females are not territorial, they have a so called 'home range'. They travel from area to area in their home range. The home ranges of several individual female cheetahs may overlap. This overlap can lead to adoption; cubs from different females can get mixed up and female cheetahs can also adopt abandoned cubs (Sengenberger, Bus & Versteege, 2018). The home ranges of female cheetahs can vary in size, but is usually approximately 960 square kilometers. This is because they follow the migration path of their primary food source: gazelles (Means, 2022). This means that they need large areas of connected habitat, for example to find males to mate (National Geographic, n.d.). Male and female cheetahs only assemble to mate. Cheetahs become sexually mature at the age of two (Wachter, 2019) and produce offspring until their death (Crosier, Byron & Comizzoli, 2022). After mating, male cheetahs leave the female cheetah and go their own way. So, male cheetahs provide no parental care, this responsibility lies with the mother. Therefore, the primary key for the survival of cheetah cubs is the mother (Gottelli et al., 2007). Cheetah mothers give birth in a lair. Lairs protect the cubs from elements and predators. Cheetah mothers also have to move their cubs to new lairs every five days to prevent detection of predators. Cheetah cubs are altricial at birth; they have their eyes closed for four to 11 days after birth and have no locomotive competency. After 12 to 13 days the cheetah cubs can start walking. Mother cheetahs may not leave her cubs for several days after giving birth to provide care and security for the cubs. During this period the cheetah mother will also not be able to eat anything. However, after this period, the mother has to leave to hunt to gain the energetic requirements for lactation, because cheetah cubs drink their mother's milk until they are four to six months old (Sengenberger, Bus & Versteege, 2018). After approximately eight weeks, the cubs emerge from the lair. They start to develop their eyesight and their survival skills through play (Enarson, 2013). After six months, cheetah cubs switch their diet to meat (National Geographic, 2018). From here on, the mother teaches the cubs to hunt (Enarson, 2013). The cubs reach their adolescence at 18 months of age and become independent (Hilborn et al., 2018).

The decline in cheetah populations is a result of several causes. One of them is their high offspring mortality (Broekhuis, 2018). There is no exact estimated percentage of the overall mortality rate of cheetah offspring and the offspring mortality of cheetahs can also differ per area. For example, a study on cheetah cub survival on the Serengeti Plains and in the Kgalagadi Transfrontier Park showed that 4.8% of the cubs that were born survived until their adolescence in the Serengeti Plains and 35.7% in the Kgalagadi Transfrontier Park (Mills, M.G. & Mills, M. E., 2013). However, according to another research, the average percentage of cubs that survive until their adolescence is 30%. Thus, the mortality rate for cheetah cubs is 70% (Live Science, 2012). Yet, another research from M. Laurenson in 1994, shows that cheetah cubs only have a 4.8% chance of reaching their adolescence. According to another research of M. Laurenson do "cheetahs suffer high offspring mortality rates compared to other large felids both before and after emergence from the lair." (Laurenson, 1994, p. 408). Different factors have an effect on the survival of cheetah cubs. These factors can be divided into two time periods: before emergence from the lair and after emergence from the lair. When looking at mortality percentages specifically before emergence from the lair, research shows that cubs only have a chance of 26.6% of surviving until emergence (Laurenson, 1994).

There are two main factors that have an influence on the mortality rate of cheetah cubs before emergence, namely: the habitat of where the cheetah cubs grow up and the nurturing behavior of the mother cheetah. The main research question of this study is then as follows: *'Why do cheetahs (Acinonyx jubatus) have a high offspring mortality rate before emergence from the lair?*

To answer this question, several sub questions have been determined:

- What does the reproductive physiology of the cheetah look like?
- What influence does the habitat of the cheetah have on the survival of cheetah cubs until emergence?
- What influence does the nurturing behavior of the mother have on the survival of cheetah cubs until emergence?

The aim of this study is to identify the main causes of why so many cheetah cubs die before emergence from the lair, to find out if better protection of the cheetah is necessary. Thus, how conservationists could make sure that cheetah cubs survive until emergence, so they have more chance of surviving until their adolescence. This protection would also contribute to reducing the current global cheetah population decline, since the number of cheetah cubs that survive to their adolescence is essential for population growth (Broekhuis, 2018). And since the cheetah is important for increasing biodiversity, it is important to study the main causes of why so many cheetah cubs die before emergence, so that researchers may use it for further research for the conservation of the cheetah.

Chapter two presents the approach of this literature study. Hereafter, the results follow in chapter three. Chapter four contains the discussion and chapter five the conclusion and recommendations. Finally, this literature study concludes with the bibliography.

2. Approach

Chapter two contains a description of how this bachelor thesis is composed. Qualitative research has been used by means of literature research.

2.1 Main question and sub questions

The main research question is as follows: *'Why do cheetahs (Acinonyx jubatus) have a high offspring mortality rate before emergence from the lair?'*

To answer this question, several sub questions have been determined:
1. What does the reproductive physiology of the cheetah look like?
2. What influence does the habitat of the cheetah have on the survival of cheetah cubs until emergence?
3. What influence does the nurturing behavior of the mother have on the survival of cheetah cubs until emergence?

While writing this bachelor thesis, information was obtained through literature research. Based on this information, the sub questions have been answered. After this, the main research question has been answered.

2.2. Literature research

Literature research answered the sub questions. Information from the literature research came from articles and scientific articles. These sources were accessed via the following databases: Google, Google Scholar, GreenI, ScienceDirect and WUR Library. When searching through online databases, the use of 'Boolean Operators' was helpful. The use of words like 'AND', 'NOT' and 'OR' resulted in more focused and productive information. The use of double quotation marks also helped with searching for a specific word combination. The literature research also included books and a video. Books have been bought via internet or have been lent via the public library.

Table 1 represents some of the search terms that were used. These search terms have come about by looking into the subject via scientific and non-scientific articles on the internet. Then by thinking of search terms per sub question and by thinking of synonyms of them.

Table 1.
Search terms

English	Offspring mortality cheetah
Factors survival cheetah cub	Offspring mortality Acinonyx jubatus
Factors survival cheetah juvenile	Death cheetah cubs
Important for cheetah cub survival	Death cheetah juvenile
Important for cheetah juvenile survival	Death cubs Acinonyx jubatus
Cheetah cub raised to independence	Reproduction cheetah
Cheetah cub raised to adolescence	Reproduction Acinonyx jubatus
Cub mortality cheetah	Threats cheetah cub
Cub mortality Acinonyx jubatus	Cheetah cub mortality emergence
Juvenile mortality cheetah	Cheetah cub mortality lair
Juvenile mortality Acinonyx jubatus	Cheetah cub mortality den

2.3 Requirements literature

It was important to only use literature that is relevant and reliable. To see if a source is relevant, it was useful to read the introduction or the abstract. It was also possible to use the 'find command' on the computer to search for specific words. The information had to be in line with the main research question and the sub questions.

When judging if a source was reliable, it was key to look at the following elements: the author and the journal, the year of publication and the accuracy.

2.3.1 The author and journal

Reliable sources have authors that are professionals. If an author has citations, is referred to by other authors, has written more on the subject and is affiliated with a scientific institution, then the author is a professional. The journal in which it is published has to be a prominent journal.

2.3.2 The year of publication

A source may be outdated if it is older than ten years. However, some sources remain relevant and can still be helpful, even if they pass the ten-year mark. So, the preference went to literature that is from the years 2002-2022, but older literature could also be used if there was no other option and the information was still relevant.

2.3.3 Accuracy

The accuracy of sources was also examined. So, it was therefore checked whether if the information was complete and if citation was used.

2.4 Publications

Table 2 shows some of the online publications that were used for answering the research questions and table 3 presents some books that were thought to be helpful before the literature research started.

Table 2.

Online publications

Author	Title article	Title journal	Year	URL
K. Laurenson	Implications of high offspring mortality for cheetah population dynamics	University of Chicago Press	n.d.	http://www.catsg.org/cheetah/05_library/5_3_publications/L/Laurenson_-_Implications_of_high_offspring_mortality_for_cheetah_population_dynamics.pdf
K. Laurenson	Early Maternal Behavior of Wild Cheetahs: Implications for captive husbandry	Zoo Biology	1993	http://www.catsg.org/cheetah/05_library/5_3_publications/L/Laurenson_1993_Maternal_behavior_in_Wild_Cheetahs.pdf
K. Laurenson	High juvenile mortality in cheetah (*Acinonyx jubatus*) and its consequences for maternal care	Journal of Zoology	1994	https://doi.org/10.1111/j.1469-7998.1994.tb04855.x

L. Marker	Aspects of Cheetah (*Acinonyx jubatus*) Biology, Ecology and Conservation Strategies on Namibian Farmlands	University of Oxford	2002	http://www.carnivoreconservation.org/files/thesis/marker_2002_phd.pdf
M. Mills	Cheetah cub survival revisited: a re-evaluation of the role of predation, especially by lions and implications for conservation	Journal of Zoology	2013	https://doi.org/10.1111/jzo.12087
A. Tommasi	Understanding the Role of Semiochemicals on the Reproductive Behaviour of Cheetahs (*Acinonyx jubstus*)	Animal Sciences	2021	https://doi.org/10.3390/ani11113140
B. Watcher	Behavior and Communication of Free-Ranging Cheetahs	Cheetahs: Biology and Conservation	2018	https://doi.org/10.1016/B978-0-12-804088-1.00009-5

Table 3.
Books

Author	**Title**	**Year**
L. Marker	A Future for Cheetahs	2014
D. Paul	Cheetah	2020
A. Sinclair	Serengeti II: Dynamics, Management, and Conservation of an Ecosystem	1995

3. Results

This chapter displays the results from the literature study.

3.1 Data collection

To answer the main question, the sub questions have been answered first. The results of the sub questions were obtained by means of literature research and the results of this literature research are described in this chapter per sub question. This literature research started at the end of April, 2022 and ended at the end of May, 2022. The main question is answered in chapter 5, in which the conclusion is described.

3.2 Sub question 1: Reproductive physiology

The first sub question is: What does the reproductive physiology of the cheetah look like? Cheetahs become sexually mature and start breeding at the age of two (Wachter, 2019) and they produce offspring until their death (Crosier, Byron & Comizzoli, 2022), which is at the age of approximately 12 years in the wild (Zagata, 2019). The estrous cycle of the cheetah lasts seven to 21 days and their estrus lasts two to six days (Brown, 2011). When a cheetah goes into estrus and is ready to reproduce, they urinate to attract males. When males find this smell, they search the area and call out the female with yelps. A female cheetah may respond with yelps, after which the male can approach the female (Hunter & Hamman, 2013). A study in 2009 showed that a specific bark of male cheetahs can also trigger the female reproductive system to ovulate. This 'stutter bark' can trigger an increase in the hormones that are responsible for ovulation (Berkovitch & Anderson, 2009). Female cheetahs are promiscuous; they mate with more than one male. Researchers have found this on the basis of two behaviors of cheetahs. First off, female cheetahs can mate with different males within a few days. This means that one litter can have numerous fathers. Second, researchers found that they mate with different males between breeding seasons and thus are not monogamous (Wildlife Conservation Society, 2007). The gestation of the cheetah lasts 94 days on average (Brown, 2011) and their inter-birth period is 15 to 19 months. Females can conceive their next litter while they are still taking care of their last litter, but they will abandon their last litter before the new cubs are born (Sengenberger, Bus & Versteege, 2018). So mostly, female cheetahs are either pregnant with young or are raising cubs for all their adult lives (Hunter & Hamman, 2013). If a female cheetah loses a litter, her oestrus cycle restarts quickly. The female goes into estrus and can be pregnant with young again within 19 days after losing her litter. This quick restart of reproduction is speculated to be an adaptation to their high offspring mortality (Hunter & Hamman, 2013). There are two other traits of cheetahs that are thought to have evolved in order to increase the survival rate due to the high offspring mortality. First, they have one of the shortest intervals between litters, compared to other large felids (Hunter & Hamman, 2013) and second: cheetahs have a large litter size compared to other felids. The average litter size of cheetahs is four, but their litters can range in size from one to eight cubs. Meanwhile, other felids have litters with an average of three, with ranges from one up to five (Tommasi, et al., 2021).

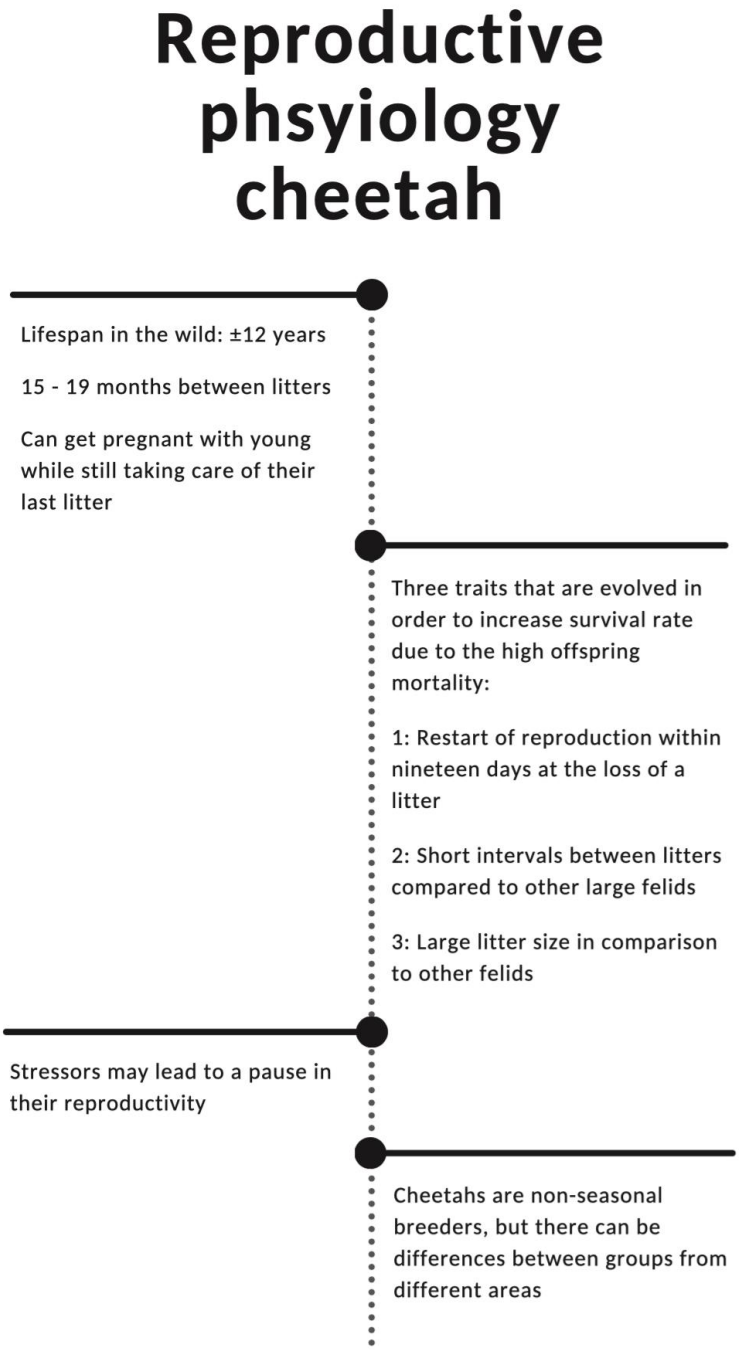
Cheetahs are shy creatures by nature (Hunter & Hamman, 2013). For example, they can get stressed when something new comes into their habitat. Stressors and distractions can lead to a pause in their reproductivity, since they suppress ovarian activity (Nyhus, et al., 2018). This also means that cheetahs will not display reproductive behavior anymore (Smithsonian's National Zoo & Conservation Biology Institute, 2015).

They are non-seasonal breeders, also referred to as continuous breeders; meaning that they can breed year-round (Crosier, Byron & Comizzoli, 2022). However, there are differences between groups from different areas. For example, in Namibia (Crosier, et al., 2007) and in the East African Serengeti (Shaw, 2019), breeding is more common during the rainy season. During this season, the grasslands are denser and thus provide better coverage (Bowman, 2019). Another reason for why

cheetahs may prefer to breed during the rainy season, is the increase in nutritional availability. During the rainy season there is more feed then during the dry season, since there is a peak in the births of gazelles during the rainy season (Sengenberger, Bus & Versteege, 2018).

To summarize the text above, the figure below shows an overview of the main findings for the first sub question.

Figure 2.
Overview sub question one



Note. Own work

3.3 Sub question 2: Habitat of the cheetah

The second sub question of this research is: What influence does the habitat of the cheetah have on the survival of cheetah cubs until emergence?

In habitat with denser vegetation and more shelters, cubs have more chance of survival. Here, cubs are less vulnerable to predators because they are less visible and lairs are less likely to be discovered. Because of this, cheetahs that live in woodlands have a higher success rate for being able to rear their cubs until they are old enough to emerge from the lair than cheetahs that live on open fields (Mills, M.G. & Mills, M. E., 2013). A study showed that 70% of the cubs that were born in the woodlands of the Phinda Game Reserve in South Africa survived to independence while only approximately 5% of the cubs that were born on plains survive to independence. This means that dense vegetation is essential for the survival of cheetah populations, when the 5% survival rate of the cubs would be the case for the whole population, the species would go extinct. However, adult male and female cheetahs that are solitaire, are more at risk of being killed by other predators in woodland compared to open plains. This is due to the fact that they have less visibility and space in woodlands to dodge an attack by other predators (Hunter & Hamman, 2013). Next to providing cover for cubs, woodlands are also helpful with maintaining the kills that cheetahs make (Rostro-García, et al., 2015). Cheetahs have a high success rate with hunting compared to other carnivores; approximately 50% of their hunts result in a kill. However, they can lose their prey to kleptoparasites, like: lions, hyaenas, or leopards. Since cheetahs are less visible in woodlands, they usually do not lose more than 5% of their prey here. While they lose 10% to 15% of their prey in open habitats (Hunter & Hamman, 2013). A threat to dense vegetation is the invasion of thorny bushes, such as the karroo thorn, the blackthorn and the boxthorn. These thorny bushes can invade grasslands, what can lead to encroachment. Native vegetation then disappears, what results in the disappearance of dense vegetation (Kgosikoma & Mogotsi, 2013).

The mother has to leave the lair to hunt in order to gain the energetic requirements for lactation. This means that the cubs may be left alone for several hours, during this time they are more vulnerable to be predated by other predators (Enarson, 2013). Therefore, it is best for the safety and thus the survival rate of the cubs, to be left alone as short as possible. This means that the habitat of the cheetah must have enough feed for the mother to be able to stay away for the shortest period of time as possible. Cheetah mothers therefore prefer habitats with intermediate concentrations of gazelles or other prey, like: springboks, nyalas or impalas and enough shelter (like shrubs or small hills). They prefer intermediate concentrations of prey, who still provide them with enough kills for the effort of hunting, instead of high concentrations of gazelles because those high concentrations are more likely to lure other predators, which leads to competition and mortal danger (Hunter & Hamman, 2013). And as for the shelter: they need it for hunting, because they use the cover to sneak up close to their prey. The type of habitat (grassland or woodland) does not matter as regards to prey availability. Cheetahs are known for their fast sprint chases towards prey on grasslands, but they actually have more skills within their hunting behavior. They are able to change their hunting methods to the habitat type they live in (Mills, et al., 2004). Next to food availability, cheetah mothers also need to refill their fluids that they lose because of lactation. This means that the habitat of the cheetah also needs to provide enough water sources (Rensch, 2018).

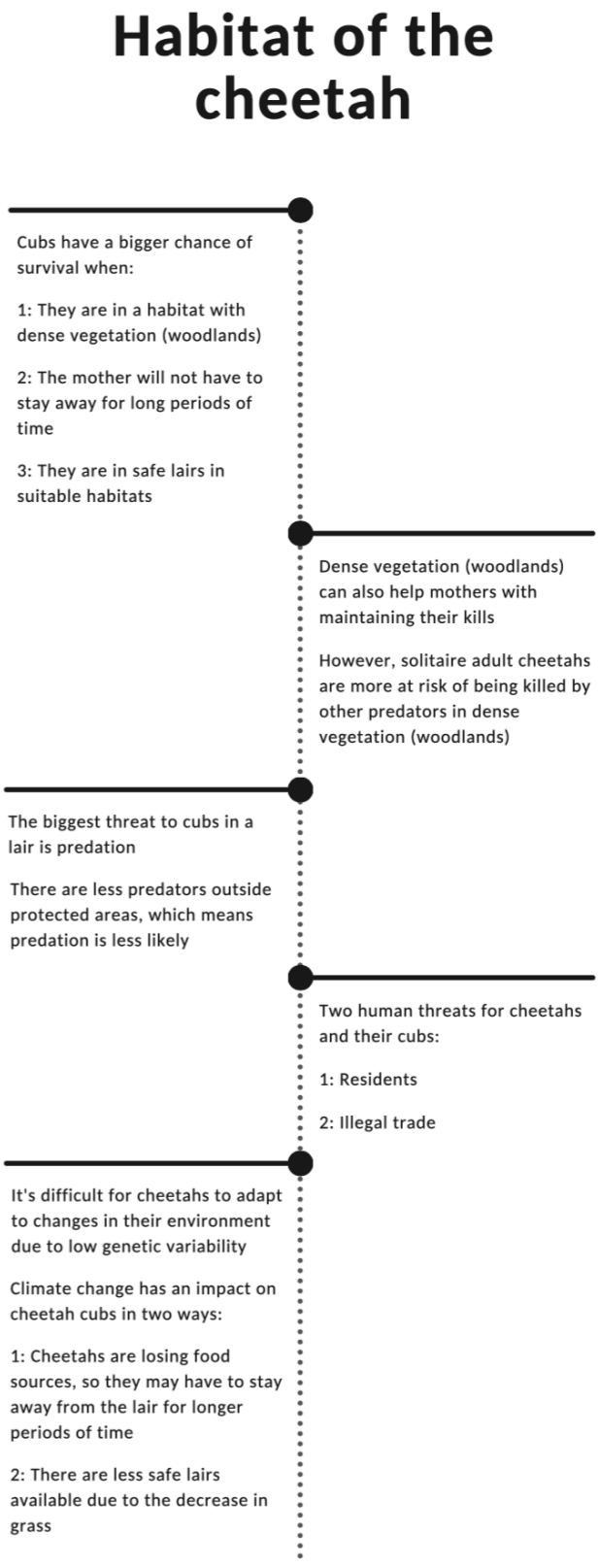
The lair is also very important for the survival of cheetah cubs until emergence. There are two reasons for this. First, the lair needs to protect the cubs from predation by, for example, lions or hyaenas. Predation is ultimately the major cause of death for cubs in the lair. Second, cubs have difficulty with maintaining their body temperature. So, if the lair does not protect them from bad weather, they might die. Accordingly, it is important that the habitat of the cheetah provides suitable lairs (Enarson, 2013). To sum up, a habitat with suitable lairs contains the following features: intermediate concentrations of gazelles, cover to sneak up on their prey and to hide and protect cubs in a lair and water sources (Hunter & Hamman, 2013).

The occurrence of cheetahs in protected areas or non-protected areas also has an influence on the survival of their cubs until emergence. As has been said above, cheetahs (cubs and adults) are killed by other predators. Protected areas contain the highest densities of these predators and since there is a negative correlation between lion and cheetah numbers, the cheetah is found more outside protected areas than inside (Hunter & Hamman, 2013). To be precise: 90% of the wild cheetah population lives outside protected areas (Marker, 2021). Non-protected areas can be safe havens for cheetahs because there are few populations of other predators there. These other predators are killed by poachers or residents outside of protected areas because they threaten livestock of farmers and can be a danger to people. So, since predation is ultimately the major cause of death for cubs in the lair and since predation by other predators is less likely outside of protected areas, cubs are more likely to survive here (Hunter & Hamman, 2013). Cheetahs are also killed by residents, but in a lesser degree because, compared to other predators, they are less of a threat to livestock and to people. Another human threat for cheetah cubs is the illegal trade. Poachers either wait for the cubs' mother to leave the lair to hunt or they kill her, in order to steal cheetah cubs from their lair (Marker, 2019). Poachers do this because they can earn money with illegal trade; extreme poverty is one of the reasons for why there is illegal trade in cheetahs. The other reason is the desire for exotic pets in the Middle East (IFAW, 2021).

Finally, it is important to note the difficulties cheetahs have in coping with change. Cheetahs have a hard time adapting to changes in their environment because they have low genetic variability due to two bottlenecks in the past (Marker, 2021). Climate change causes multiple problems for cheetahs, but only two of them are relevant for the survival of cheetah cubs until emergence. Climate change causes environmental change, the consequences of this causes prey populations to suffer and to decline in population numbers. Climate change causes more droughts, which decreases the availability of grass. Prey who have a grass diet have less food available, so they suffer mortality (Abraham, et al. 2019). Therefore, cheetahs are losing food sources and may have to stay away from their lair for longer periods of time, which puts their cubs at more risk (Njeru, 2012). This decrease in grass availability also results in less dense vegetation in their habitat (Abraham, et al. 2019). This means that there are fewer safe lairs available, with the result that cubs are more vulnerable to predation (Hunter & Hamman, 2013).

Figure 3 shows an overview of the main findings for the second sub question.

Figure 3.
Overview sub question two



Note. Own work

3.4 Sub question 3: Nurturing behavior

What influence does the nurturing behavior of the mother have on the survival of cheetah cubs until emergence? This is the third and last sub question to be answered in the results.

First, cheetah mothers have to be able to find a suitable lair to give birth in. This is not only important for the protection of their cubs against bad weather and other predators, but also to be sure that they can provide for the needs of their cubs. When the gestation period is ending, they will spend time to roam their habitat to find a suitable lair. As stated in paragraph 3.3, suitable lairs are in habitats where there is intermediate concentrations of gazelles, concealment to sneak up on their prey and water sources. If the lair is close to these three things, then the mothers can provide for the needs of their cubs. As for the protection of the cubs, the lairs have to be hidden, so mothers need to be able to find spots where there is thick vegetation. If there is no vegetation available where lairs can be hidden, mothers will have to find different solutions. They can give birth in a cave, an abandoned burrow from a jackal or striped hyena or in a drainage line for example. If the mother has to find a suitable site for a lair in a drainage line, then it is important that they find a suitable site high on the drainage line, because there is danger of flooding on the bottom of drainage lines (Hunter & Hamman, 2013). Another way of cheetah mothers protecting their cubs in the eight-week period before emergence is by moving their cubs to new lairs every five days or so, to prevent detection from predators. Predators may detect cubs in a lair by following the cheetah mother or by scents in the lair that develop over time; this scent originates from the cubs, which attracts other predators (Hunter & Hamman, 2013). Cheetah mothers move their cubs by carrying each cub in their mouth by the scruff. This action actually relaxes the cub's nerves and helps to calm them when they are on the move (Onguma, n.d.). Cubs that are born in areas where there are less or no other large predators, like outside protected areas, may never be moved to another lair by their mother (Hunter & Hamman, 2013).

The first few days after birth, mothers will not leave the lair, they stay with their cubs. They purr quietly to their cubs to comfort them and they provide warmth, security and nutrition (Marker, 2021). The eight-week period in the lair before emergence is one of the most threatening times for cheetah cubs. Cheetah mothers try to protect them during this time in different ways. One of them is that mothers rarely sit up when they are in the lair to rest or to nurse her cubs, to avoid detection by other large predators (Caro, 1994). Compared to lone female cheetahs, they also spent a great part of the day being vigilant and observing their surroundings. Vigilant mothers monitor their environment more actively for danger, so that they can notice other large predators at bigger distances (Salim, 2020). Cubs are even more vulnerable when they are left alone in the lair from time to time while they are still dependent and defenseless. One way of mothers dealing with this is trying to prevent detection of the lair from other large predators. So, if they have to leave the lair to hunt, they leave a few hours after sunrise and return mid-afternoon or after dusk. During these times, other large predators are usually inactive, so that minimizes the chances of being noticed. In addition to this, they have an increased vigilance within one kilometer of the lair when they return from hunting (Caro, 1994). Hunting before emergence of the cubs is mainly important for the mother; only the mother eats this meat, the cubs still only drink milk. However, successful hunts of the mother are also of value for the cubs, because the mother needs these kills to gain the energy to be able to provide the cubs with milk (Sengenberger, Bus & Versteege, 2018). Therewithal, the availability of milk can affect the growth rate of the cubs. If the food intake of the mother decreases, there is also less milk available for the cubs, which results in lower growth rates (Laurenson, 1994). Growth rate is an important factor in infant's survival chances, so adequate nutrition is needed for the developmental changes of cubs (Bell, et al., 2011). Therefore, it is important that mothers are able to hunt effectively, so that they are able to provide for their cubs. This means that the mother must be a good hunter. There are three things that can affect the hunting skills of mothers. First, their age. Adolescent and young cheetahs have difficulties with catching large prey. Second, they have to be able to situate their lairs in an area where there is enough feed and last, they need to be equipped

with good hunting skills (Laurenson, 1994). Cheetah mothers can adapt their behavior and use different techniques to minimize interaction with other large predators. For example when they are hunting. They make sure they have a short chase and then they kill the prey by suffocation. This technique allows them to be silent, what makes them more difficult to notice. Dragging their kills into cover immediately after suffocating them is also a behavior that minimizes interaction with other large predators. This can help with maintaining their kills, but it also may reduce cheetah mortality, what increases the chance of the mothers returning healthy and safely to their cubs in the lair (Durant, 2000).

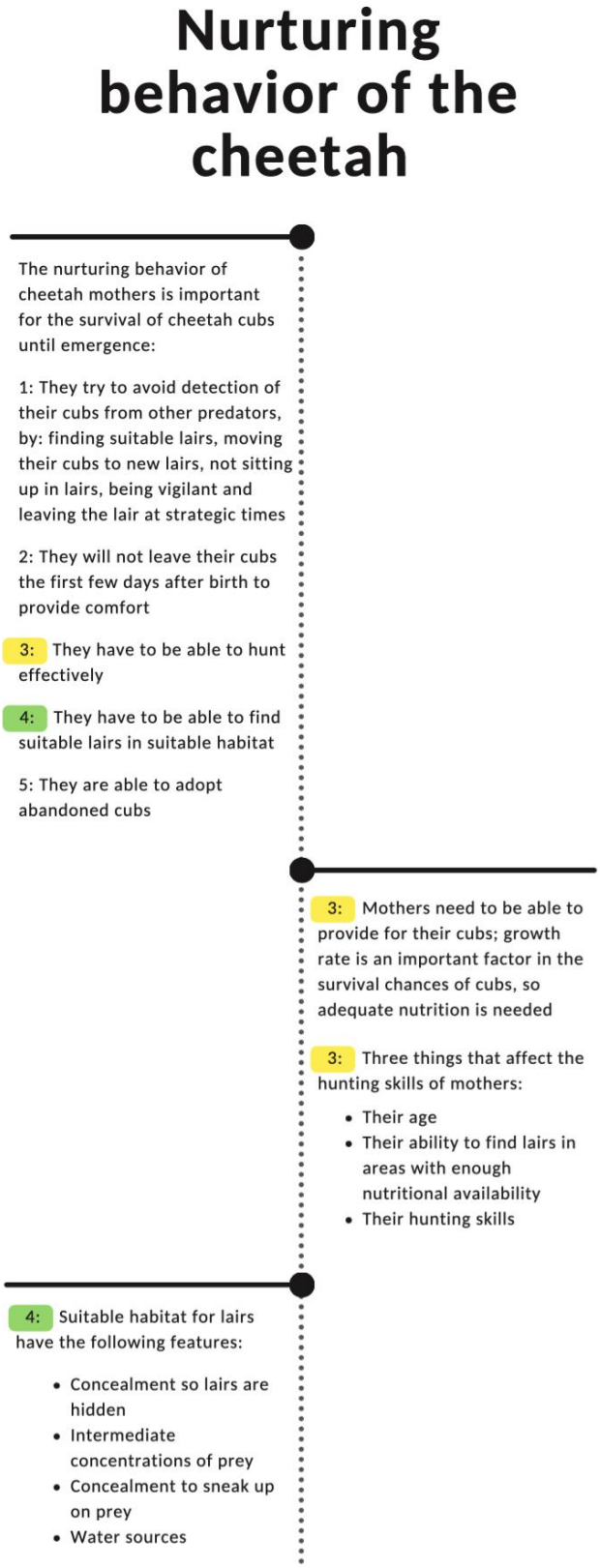
Cheetah mothers do not normally abandon their cubs, but sometimes it does occur due to various reasons (Mohamed, 2021). If a cheetah only conceives one cub, or if only one cub survives the birth, then the mother abandons or kills this singleton. They do this so that their oestrus cycle resumes quickly, so that they can go into estrus and can be pregnant with young again with the goal of more cubs surviving to adulthood this time (Navarro, 2021). Contrary to this reason, sometimes cheetah mothers have no choice when abandoning their cubs. It may happen when cheetah mothers are too scared to come back to their cubs after residents chase them away (Mohammed, 2021) or when they are forced to cover too big of a distance when hunting for food. Abandoned cubs are sometimes adopted by other mothers. Adoption is actually uncommon in wild cats, so why they do this, is still unclear. Adoption is the only hope for survival of abandoned cheetah cubs; after a cub is adopted, they are raised with the rest of the litter (Hunter & Hamman, 2013).

When cubs are eight weeks old, they are ready to follow their mother on her travels. Now that they have emerged, the mother will also have to focus on teaching them how to survive on their own, instead of just feeding and protecting them (Pettorelli & Durant, 2007). They have to start teaching their cubs survival strategies, which improves the survival chances of the cubs. Cubs learn these strategies by observing their mother closely (Mara Meru Cheetah Project, 2018). After approximately 18 months, the mother will separate herself from her cubs (Cheetah Conservation Fund, n.d.). This may be because her new litter will almost be born, as has been explained in chapter 3.2, but it does not have to be (Sengenberger, Bus & Versteege, 2018).

To summarize: the nurturing behavior of cheetah mothers is a primary key in the survival of cheetah cubs. They have to be able to find multiple suitable lairs to hide their cubs, they have to be careful to not give away the position of their cubs, they have to be able to hunt effectively to provide for their own nutritional requirements but also for their cubs and they can adopt abandoned cubs.

The figure below shows an overview of the main findings for the last sub question.

Figure 4.
Overview sub question three



Note. Own work

4. Discussion

This chapter describes the discussion of the literature research and the associated results.

The aim of this study was to identify the main causes of the high mortality rate of cheetah cubs before emergence from the lair. Conservationists can use this knowledge to find out how they could make sure that cheetah cubs survive until emergence. When they survive until emergence, they have more chance of surviving until their adolescence, which also helps with reducing the decline of cheetah populations and with increasing biodiversity.

To get the results, a literature research has been done. Sources were accessed via various databases, but Google Scholar was used the most. This database had the most scientific articles that were accessible via Aeres. Information was never blindly acquired, sources were always examined to see if they contain reliable data. For instance, the source had to be reliable and authors had to be professionals. One way of examining this was by looking at if the journal, that the article is published in, is prominent. Authors were googled to examine their background and to see if they have written more about the cheetah, or if they have done more research on the cheetah. The accuracy of sources was also examined by checking if the information was complete and if citation was used. Most of the publications that were stated in chapter 2 have been used; this list has been expanded while writing the results and the book of D. Paul has been replaced by a book of L. Hunter and D. Hamman. This book had more information and the authors seemed to have more experience. All in all, there was made use of a wide variety of reliable sources. This variation can be seen in for example: different authors and different kinds of sources like articles, scientific articles, books and a video.

However, there is always room for improvement. Next time it would be better if (almost) all the information will be double checked. So, that when a piece of information is found, it will be examined if this information is also reflected in other researches or other sources. This has been done with this literature research, but not as extensive as it could be, because of time shortage. So, next time it can be done more extensively to be more certain that everything that is written down are really true facts. Some researches that were used to answer the sub questions were quite old (from 1994). The information in these researches was valuable for this literature research, so therefore it was used regardless of the year of publication. The use of sources that are older than ten years has also been described in chapter two (the approach).

Some topics were not covered extensively in this thesis, because not enough research has been done on these topics. For example, little is known about what causes stress in cheetahs. So, this thesis only covered this topic briefly. The few scientific researches that have been done on this topic, are about cheetahs in captivity. It is not known what exact causes of stress in wild cheetahs result in a pause in reproductivity and how big of a problem this pause is for the survival of cheetah populations. Additionally, during this literature research it was found that there is also little knowledge about what causes the high mortality rate of cheetah cubs in deserts, so desert cheetahs have not been considered. When trying to find researches on how many mothers die because of predation with the result that their cubs die too, some contradiction was found. A study in 2011 suggested that the conservation of lions might lead to the extinction of cheetahs, but a study in 2016 suggested that an increasing lion population does not result in a decrease of cheetah numbers. There is another topic that has not been considered for this literature research, even though there is information and scientific research available: the low genetic variability of cheetahs. Research on this has not been done extensively for this thesis because of time shortage. So, the research on the influence of the low genetic variability of cheetahs can be done more extensively. For example, it can be researched more whether the inbreeding, that is taking place because of the two bottlenecks in the past, can lead to mutations that can be passed on to offspring and if that makes surviving harder for them or not.

As for the results, sometimes information of sources differed, this was the case with numbers. For example, different sources stated different ages of when cubs reach adolescence and become independent. The ages of 14 months, 18 months and 20 months have been found. The age of when cubs leave the lair also differed per source. Eventually, the age was chosen that occurred in the most sources, that were also reliable. Prior to the literature research it was expected that predation is the main cause of the high mortality rate of cheetah cubs in the lair, this turned out to be true. However, there are also many new insights. For example, about their skills within their hunting behavior and how they are able to change their hunting methods to the habitat type they live in and also the effect of climate change on their ecosystem.

The results of this literature research may help conservationist understand what the causes are of the high offspring mortality rate of cheetah cubs before emergence from the lair and what is needed to make sure that cheetah cubs survive until emergence.

5. Conclusion and recommendations

This chapter answers the main question. To get an answer to this question, a literature research was conducted. Below, the results of the sub questions will be summarized first, where after the main question will be answered.

5.1 Conclusion

This thesis is about the high offspring mortality rate of cheetah cubs before emergence from the lair. So, the aim was to identify the main causes of why so many cheetah cubs die before emergence from the lair. Conservationists can use this knowledge to find out how they could make sure that cheetah cubs survive until emergence, so they have more chance of surviving until their adolescence. This protection would be needed to reduce the current decline in cheetah populations, which would also help with increasing biodiversity.

Sub question 1: What does the reproductive physiology of the cheetah look like?

What is interesting about the reproductive physiology of the cheetah is that there are three traits that are thought to be evolved as an adaptation to their high offspring mortality. Namely: they can restart their oestrus cycle quickly after losing a litter, they have one of the shortest intervals between litters and they have a large litter size compared to other felids. Besides, they start breeding around the age of two and produce offspring until their death. The gestation period is approximately 94 days and their inter-birth period is 15 to 19 months. Cheetahs can conceive their next litter while they are still taking care of their last litter, so female cheetahs are either pregnant or raising cubs for all their adult lives. They can breed year-round, but some researches showed that cheetahs prefer to breed during the rainy season. Finally, since cheetahs are shy creatures, stressors and distractions can lead to a pause in their reproductivity.

Sub question 2: What influence does the habitat of the cheetah have on the survival of cheetah cubs until emergence?

The habitat of the cheetah influences the survival of cheetah cubs until emergence in different ways. First of all, the presence of dense vegetation is important. Predation is ultimately the major cause of death for cubs before emergence; cubs have more chance of survival in habitats with dense vegetation because they are less visible to other predators. In addition to this, vegetation is also important for the mother to gain the energetic requirements for lactation, since cover helps with hunting. Finally, vegetation is also important for providing suitable and safe lairs, which is necessary for the survival of cheetah cubs until emergence. However, adult cheetahs are more at risk of being killed by other predators in dense vegetation. The nutritional availability of the habitat also influences the survival of cheetah cubs until emergence. The habitat must have enough feed for the mother to be able to stay away from the lair for the shortest period of time as possible. Climate change also shows the importance of having enough feed; prey populations are declining in numbers due to droughts, which means cheetahs are losing food sources and may have to stay away from their lair for longer periods of time, which puts their cubs at more risk. Next to food, is water also important for lactation, so the habitat of the cheetah would also need to provide enough water sources. The number of predators in the habitat also has an influence on the survival of cubs until emergence, since predation is ultimately the major cause of death for cubs in the lair. Lastly, people in their habitat can also be a threat to cubs. Their mothers are killed or they are taken away to be kept as pets.

Sub question 3: What influence does the nurturing behavior of the mother have on the survival of cheetah cubs until emergence?

The nurturing behavior of cheetah mothers is important for the survival of cheetah cubs until emergence for five different reasons. Firstly, they try to avoid detection of their cubs by other predators, by: finding safe lairs, moving their cubs to new lairs every five days or so, laying low in

lairs, being more vigilant and by leaving the lair at strategic times. Second, they will not leave their cubs the first few days after birth to provide comfort, warmth, security and nutrition. The third reason as to why the nurturing behavior of cheetah mothers is important for the survival of cheetah cubs until emergence has to do with them being able to hunt effectively. They need good hunting skills to be able to provide their cubs with enough milk to support their growth rate, which is important for their survival chances. Fourth, mothers should not only be able to find a safe lair, they should also be able to find this lair in a suitable habitat. Since habitats also have an influence on the survival of cheetah cubs until emergence, like sub question two shows. Finally, cheetah mothers are able to adopt abandoned cubs, which gives them a second chance in life.

The main question of this literature research is: Why do cheetahs (*Acinonyx jubatus*) have a high offspring mortality rate before emergence from the lair?
Cheetahs actually have an adequate reproductive physiology in the wild, especially because they have evolved different traits as an adaptation to their high offspring mortality and because they are practically either pregnant or raising cubs for all their adult lives. The results showed different causes for the high offspring mortality rate before emergence from the lair, with predation by other large predators being the main cause. Other causes that explain the high offspring mortality rate before emergence are: kills by residents, illegal trade, shortages of food and/or water and climate change. Other large predators can kill mother cheetahs, with as a consequence that the cubs will die. Except if they get adopted. But, large predators usually kill the cubs they find in the lair. Since cubs are more difficult to find by predators in dense vegetation, woodlands are pivotal for the survival of cubs. This, in turn, is important for the conservation or growth of cheetah populations, since the survival rate of cubs influences that. Residents can also kill the mother cheetah, what results in dead cubs and poachers may take cubs from the lair to sell them. Food shortages in the habitat can lead to offspring mortality due to two reasons. First, if there is not enough food, the mother will not have the energetic requirements for lactation which means that there is less milk available for the cubs. This results in lower growth rates of the cubs which lowers their survival chances. And second, cubs are more vulnerable to be predated by other predators when they are left alone by their mother. Mothers may even abandon their cubs when they are forced to cover too big of a distance when hunting for food, which also results in dead cubs unless they are adopted by another female cheetah. Climate change also contributes to a reduction of the availability of food for mothers to gain the energetic requirements for lactation. A suitable habitat with enough food, water and cover and sufficient nurturing behavior of the mother cheetah can protect cubs to a certain extent from predation and from there not being enough food or water.

5.2 Recommendations

The aim of this literature research was to identify the main causes of why so many cheetah cubs die before emergence from the lair. This knowledge can help conservationists in their efforts to make sure that cheetah cubs survive until emergence, so they have more chance of surviving until their adolescence. This protection would be needed to reduce the current decline in cheetah populations; if the current situation does not change, cheetahs could go extinct. A reduce in de current decline would also help with increasing biodiversity. So, conservationists are the target audience of this thesis.

It is concluded that cheetah cubs have a high offspring mortality rate because of the following reasons: predation by other large predators, residents, illegal trade, food or water shortage and climate change.

By means of the results of this research it can be recommended to reduce the risk of predation of cubs by making sure there are safe lairs available. Safe lairs are hidden in dense vegetation. This way, cubs are harder to detect by predators. Woodlands are dense vegetation, so the preservation of these would also be important to make sure there are safe lairs available. Another way of preserving

or returning dense vegetation is by 'bush removal'. With bush removal, thorny bushes are being removed completely or they are poisoned. This way, encroachment can be prevented or reversed, which helps with keeping or growing dense vegetation.

As regards to residents and poachers: it is important that they are also taken into consideration. Research shows that 90% of the wild cheetah population lives outside protected areas, where residents and poachers are a threat to cheetahs and their cubs. Education for residents and rangers that also patrol outside protected areas against poaching may help.

Climate change and its consequences is not something that can be stopped or mitigated easily. The dangers of climate change for cubs before emergence from the lair is drought. This results in less prey and less water, which makes it harder for cheetah mothers to gain the energetic requirements and water that is needed for lactation. Which in turn brings the growth rate of cubs in danger what reduces the chance of survival.

In short, the following recommendations have been made for conservationists as a result of this literature research:
Short term:
- Make sure thorny bushes are removed; this way encroachment can be prevented or reversed what helps with maintaining or creating safe lairs for cheetah cubs.

Long term:
- Ensure to preserve woodlands, since dense vegetation is pivotal for the survival of cubs.
- Educate residents on what to do and who to call when there is a cheetah close to their land or livestock.
- Employ and train rangers to patrol outside protected areas to protect wildlife (under which cheetahs).
- Actively spread knowledge to decisionmakers on the consequences of climate change on the cheetah and other endangered species.

If this research were to be continued, it would be interesting to do more extensive research on the low genetic variability of cheetahs. For example, on what the consequences are of inbreeding and the low genetic variation for the survival of cheetah cubs. A few follow-up researches that align with the topic of this thesis would be interesting. First off, a study on what causes mortality in cheetah cubs after emergence would be an interesting follow-up research. Including what would be needed to increase the likelihood of their survival. Second, a study on what causes stress in wild cheetahs that results in a pause in reproductivity and how big of a problem that pause is for the survival of cheetah populations. And finally, more research on the number of mothers that die because of predation with the result that their cubs die too and the meaning of this for the population numbers of cheetahs.

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