Master's Thesis – Master Sustainable Business and Innovation

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WHY RAISE THE DEAD?

AN EMPIRICAL ANALYSIS ON HOW AND WHY SPECIES CANDIDATES ARE CHOSEN FOR DE-EXTINCTION PROJECTS

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Abstract

Introduction

Nature conservation is more important than ever, since biodiversity is plummeting and the existence of many ecosystems is threatened. Next to nature itself, this is also harmful for human society. De-extinction is a recent development within nature conservation. With de-extinction an extinct species is recreated through back-breeding, cloning or genome engineering. Discussions focus on the release and management of the resurrected species. Less attention is paid to the choices that are made regarding species selection, although this partly determines the impact on the environment. To create an holistic overview of these choices so better informed decisions can be made, this thesis explains how species candidates are chosen in de-extinction projects.

Theory

De-extinction is proposed as a nature conservation method, but the choices for candidate species are not made solely for conservation purposes. In this thesis, the theoretical framework by Dalrymple (2006) is used to map how users, researchers, funders, and public value interact and shape the decision-making. This builds upon the Social Construction of Technology, which explains the influence of society on technology development.

Methods

In total, nine de-extinction projects were identified. Semi-structured and structured interviews were held with relevant actors, and a systematic literature research was performed. All data were coded in Microsoft Excel, which resulted in a list of motives. The theoretical framework was used to identify patterns, and to interpret the findings.

Results

Two main findings were discovered. First, seven motives were found to play a role in the selection of species candidates. These motives strongly depart from existing literature on how species candidates should be selected. Second, animal charisma is an essential condition for any species to be selected. The interaction between the actors creates an environment in which charismatic species are structurally favoured as de-extinction candidates.

Discussion & Conclusion

This favouritism for charismatic species is recognised in the literature on nature conservation. This thesis, however, gives a first holistic insight in the preferences for species candidates in de-extinction projects, and it is the first research that uses such a framework to analyse this. The favouritism for charisma gives reason for concern, since this may deflect from achieving optimal conservation outcomes. Therefore, the actors must create new circumstances in which the researcher can make different choices. Overall, this thesis contributes to understanding how nature conservation will be shaped in the future, which will help the actors to make better informed decisions regarding de-extinction candidates.

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Introduction

'There is no survivor, there is no future, there is no life to be recreated in this form again. We are looking upon the uttermost finality which can be written, glimpsing the darkness which will not know another ray of light. We are in touch with the reality of extinction.' (Hough, 1933, p.29).

This statement was written by Henry Beetle Hough in 1933 after the death of the last Heath Hen, resulting in the extinction of the species. Unfortunately, this is not a single event. In all history of life on Earth, five mass extinction events have occurred so far. This means a loss of over 75% of all species. Scientists have increasingly become to believe that we are currently on the verge of, or already living in the Sixth Mass Extinction, which is primarily induced by humans (Kolbert, 2014; Barnosky et al., 2011; Ceballos et al., 2015). A rich biodiversity is important for sustaining a stable, resilient ecosystem. As many endangered species play a key role in their ecological 'community', their extinction can trigger a cascade of extinctions that may lead to the collapse of an ecosystem (Christianou & Ebenman, 2005). This is not only a loss for the ecosystem itself, but also for humans, who rely on biodiversity to provide goods and services to human society (Gamfeldt et al., 2008).

Conservation biology has always looked at technology sceptically. Biologists created the basis for nature- and biology conservation at the end of the 19th century, when the value and importance of nature became more recognised (Jongman, 1995). Soulé (1985, p.727) described conservation biology as a crisis discipline that 'addresses the biology of species, communities and ecosystems that are perturbed, either directly or indirectly, by human activities or other agents. Its goal is to provide principles and tools for preserving biological diversity'. Conservation biologists were advising government agencies and private organisations mostly on 'field work', such as the design of national parks and the frequency and kinds of management in existing protected areas and wildlands. Technology and technological development were seen as 'a major threat to society and nature' and conservation biologists had the task to 'help mitigate technological impacts' (Soulé, 1985, p.733).

However, in recent years nature conservation has come to embrace technology as an ally rather than an enemy. For example, digital technological advancements have made it possible to track animals through tags, camera traps and drones at previously inaccessible locations. This has resulted in super specific, almost real-time data that opens up many new possibilities (Arts et al., 2015). Most of these devices and methods were originally developed for other purposes, and were adopted by the conservation community in a later stage. More recently, conservation biologists and researchers have started to actively design and develop innovative solutions for specific conservation problems (Berger-Tal & Lahoz-Monfort, 2018). An example of this is the development of synthetic biology. This is a field that chemically synthesizes DNA to create or change organisms with new characteristics. Scientists believe this will bring a major shift in contemporary nature conservation. Until now, conservation has been mainly about reducing losses and maintaining a desired state. With synthetic biology, it becomes possible to alter parts of the system to prevent losses, and even bring lost species back into the system (Redford et al., 2013; Donlan, 2014).

This is a game changer for conservation biology. The extinction of species has always been considered final and irreversible. Now, with the introduction of synthetic biology, we might be at the start of a new era, where extinction is no longer final and life can be recreated from an extinct animal. This innovation is called *de-extinction*, or *resurrection biology*. With de-extinction an extinct species can be recreated by purposefully adapting a living organism through means of various breeding techniques (Novak, 2018; IUCN, 2016). Three different techniques are used for de-extinction, namely selective breeding, cloning and genome engineering (IUCN, 2016; Novak, 2018; Shapiro, 2017). These techniques will be discussed more extensive in the following chapter, with examples of several de-extinction projects such as the Auroch, the Woolly Mammoth, and the Passenger Pigeon.

De-extinction has gained significant attention over the last years and is the topic of many ethical, political and ecological discussions (Seddon et al., 2014; Sandler, 2017). Much of the debate focuses on practical issues such as the release and management of any resurrected species. Questions are raised on subjects like the viability of the species' living area (Seddon et al., 2014) and the effect of the species on the existing ecosystem (Camacho, 2015). On the other hand, ethical issues include suffering of the individual (Kasperbauer, 2017) and whether de-extinction can actually be justified (Cohen, 2014).

Much less attention is paid to the choices that are made in the process of resurrection itself (Shapiro, 2017). However, this is a very important step in the process. Every step that comes next, including the release and management that are already widely debated, depends partly on the choice of species that is made. The revival of different species will have different impacts on a sustainability-, conservation- and societal level. Therefore, it is crucial to understand how the process of choosing a candidate species works and what the decisions are based on. Turner (2017) also stresses the importance of filling this gap in the literature. He explains that humanity will shape the macroevolutionary future by selecting de-extinction candidates, and therefore make the decision which species will become extinct and which species will be revived. It is crucial to develop theoretical guidance and clarification on making these important decisions.

In the current literature, several aspects influencing choices in de-extinction have been suggested but these have not yet been empirically studied. Examples of authors that hypothesise about aspects are Kasperbauer (2017) who mentions public attitude and animal charisma, and Sandler (2017) who writes about cultural importance and the influence of costs. The International Union for the Conservation of Nature (IUCN) created a document with guidelines on de-extinction (IUCN, 2016), and Seddon et al. (2014) propose a framework on what factors should be taken into consideration. However, both frameworks state how the choices *should* be made. We do not yet know how the choices are *actually* made in practice, and what factors *actually* play a role. Also, we can assume that the actual choices that are made do not follow either of the proposed frameworks or guidelines. A good substantiation of this is the fact that both frameworks are based on de-extinction as a nature conservation practice. However, not all candidate species seem to have a significant conservation value that would benefit the ecosystem. For example, the Gastric Brooding Frog, a candidate species from Australia, draw great interest for its ability to turn its stomach into a womb, but its role in the ecosystem is not known to be crucial or unique (Yong, 2013). Also, both frameworks state that the extinction threat has to be under control. However, for various candidate species this is not the case. Therefore it can be assumed that the actual choices are based on other motives than solely the ones suggested in the guidelines.

The literature that does include an empirical study of the choice for candidate species, only focuses on one or a few aspects. For example, Turner (2017) demonstrates that the species choice is influenced by animal charisma and cultural or symbolic importance, but he does not mention the possibility for, for instance, the conservation benefit that might have affected the choice. Understanding the plethora of factors that play a role is important for understanding how species are eventually chosen, and why. My aim is to fill this gap and to provide a better understanding of the choice for candidate species. Therefore, this research aims to answer the following question:

How are species candidates chosen in de-extinction projects?

In the projects that are targeted, researchers have selected a species candidate and started working on their de-extinction. This makes it possible to empirically study this selection process.

For this, qualitative semi-structured interviews with scientists working on the projects were held. This is the most logical choice because the scientists are the ones making the decision, and thus the ones who may be influenced by their surroundings. Additional interviews were held with users, who are thought to influence the researcher. Interviews are the best way to gather data because it allows for primary data to be collected. The interviews were transcribed and interpreted in Microsoft Excel. Also, literature research was done to substantiate and criticise the findings.

To map the different actors that are involved in the decision-making process of the researcher, the theoretical framework by Dalrymple (2006) is used. This framework highlights which actors and relations influence decision-making and priority-setting by researchers.

Investigating the choice for candidate species in de-extinction projects contributes to understanding the role of such innovations in nature conservation. As explained, nature conservation is becoming more and more technological and technological innovations are increasingly important within the field of biology conservation. De-extinction, as being one of the latest innovations in that field, is a perfect example of this. Understanding how choices are made in de-extinction projects will therefore help to understand how technology changes the choices that are made and the priorities that are set in the broader field of nature conservation. Therefore, this study contributes to understanding how new technologies are shaping the field of conservation biology.

This study is societally relevant as well, because if we better understand why a species is chosen as a de-extinction candidate, this can help scientists as well as other involved actors to make a better informed and more conscious decision that is both scientifically and morally justified. If more knowledge and information about the choice for de-extinction candidates is available to the public, this might raise support and interest for the innovation itself as well as for the broader topic of nature conservation. It might also provide transparency that enables them to disagree. This allows for more democratic debate about this controversial and potentially impactful technology.

De-extinction technology in a nutshell

In this chapter, first the definition of de-extinction is assessed. Then, the possible techniques are explained more extensive.

In the literature there is much debate about the definition for de-extinction, and what it should or should not include. Some definitions merely describe the revival of an extinct species (Cohen, 2014; Kasperbauer, 2017). However, other authors argue that true revival is not possible, since the development and behaviour of a species is determined by more than just genetics (Slater & Clatterbuck, 2018; Shapiro, 2015a). Therefore, some authors intentionally refer not to the resurrection of an extinct species, but to the creation of an ecological replacement for that extinct species (IUCN, 2016; Novak, 2018).

This debate shows that the motives for de-extinction and the possible outcomes are still not well understood, and more research is needed to create a full and concrete picture of the possibilities of this new field. One commonly used definition that I will use for de-extinction is: 'de-extinction is the ecological replacement of an extinct species by means of purposefully adapting a living organism to serve the ecological function of the extinct species by altering phenotypes through means of various breeding techniques, including artificial selection, back-breeding and precise hybridization facilitated by genome editing' (Novak, 2018, p.5).

De-extinction can be done through three different techniques, or pathways. Selective breeding, or back-breeding, is the first pathway. To do this, the closest living relative or a hybrid form of the extinct species is selected. From this relative, the individuals that mostly represent the desired traits of the extinct species are targeted and used to breed these traits back into the population (IUCN, 2016; Novak, 2018; Shapiro, 2017). In the 1920s, the brothers Lutz and Heinz Heck were perhaps the first to start a back-breeding project on an extinct animal. They began a breeding project to try and create an animal closely resembling the Auroch. This is the wild ancestor of domestic cattle and it went extinct in 1627 (Shapiro, 2017). Today, back-breeding projects targeting the Auroch are still active. Currently the Tauros Programme is working on its fourth generation of the Tauros, which is how they call the animal that needs to genetically resemble the Auroch (Born to be wild, n.d.). A limitation of breeding is that it takes several generations to bring forth the desired traits. Also, the result will never be genetically identical to the extinct species (IUCN, 2016).

Cloning is the second pathway. With cloning, the desired result is a genetic duplicate of the target species. For this, scientists need an intact cell nucleus (cell core) from the extinct animal. This nucleus can then be inserted into the egg cell of a close living relative from which the nucleus has been removed. This is called Somatic Cell Nuclear Transfer (SCNT). When the cell starts dividing, the embryo can be planted into the suitable host (Novak, 2018; Shapiro, 2017; IUCN, 2016). The first cloned amphibian was a Northern Leopard frog in the 1950s and the first cloned mammal was Dolly the Sheep in 1996 (IUCN, 2016). So far, successful cloning where the animal survived has only been done on extant species. A cloned Bucardo, also known as Pyrenean Ibex, which is an extinct subspecies of the Spanish Ibex, was born alive in 2002 but died after several minutes due to respiratory problems (Folch et al., 2009). Next to the cloned animal's health issues, cloning of extinct species poses more major limitations. First, it can be challenging to find a suitable host for extinct mammals (a Woolly Mammoth, for example). Second, many eggs and embryo plantations are necessary to obtain even one healthy animal that has quality of life. Also, multiple separate clones are needed to ensure population restoration. This means that a lot of intact cells with different genes have to be available (Novak, 2018). A major limitation that makes it impossible to clone long-extinct species, is the fact that for cloning, intact living cells are necessary. However, the decay of DNA starts directly after death. Therefore, cloning is only possible for species that went extinct after the technique for preserving living cells was invented. Living, intact cells are not stored from species that went extinct before the technique existed (Shapiro, 2015b).

The third pathway may help to overcome that last limitation of cloning. This pathway is genome engineering. A genome, which is a full set of DNA, is necessary for any species to live. With genome engineering, DNA can be derived from preserved tissue of the extinct animal (IUCN, 2016). The genome can be put together with pieces of DNA found on different tissue samples. However, for long-extinct species the genome is often not complete. To solve this, the genome of the extinct species is aligned next to the genome of the closest living relative. Then, gaps in the extinct species' genome can be filled with DNA of the relative, and DNA of the extinct species can be spliced with the living relative's DNA to create a species with the traits and resemblance of the extinct animal (IUCN, 2016). This was a very expensive, time consuming and difficult practice, but a new gene-editing technology called CRISPR/Cas9 (Clustered Regulatory Interspaced Palindromic Repeats) has made genome engineering cheaper, quicker and more precise (Redman et al., 2016). This has accelerated the developments in gene editing and the (re)construction of genomes of extinct species. Full genome sequences have already been constructed for several extinct animal species such as the Woolly Mammoth (Shapiro, 2017; Lynch et al., 2015; Palkopoulou et al., 2015), the Auroch (Shapiro, 2017; Park et al., 2015) and the Passenger Pigeon (Shapiro, 2017; Hung et al., 2014). Limitations of this technique are that finding a suitable host may be difficult, as well as extracting enough viable DNA from the extinct species. Also, the resulting hybrid will not be identical to the extinct species.

Theory

The scholarly literature on de-extinction focuses on ethical and environmental issues that come with the possible de-extinction of any species. These challenges are, for example, that the cause for extinction is still there (Kasperbauer, 2017; Seddon et al., 2014), that species might become invasive (Kasperbauer, 2017; Cohen, 2014; Camacho, 2015), and that there are animal welfare concerns (Kasperbauer, 2017). In an attempt to overcome these challenges, both IUCN (2016) and Seddon et al. (2014) propose a framework that states how candidate species should be selected, and what factors should be taken into account. Both frameworks are based on selecting species that would theoretically bring conservation benefits, since they propose de-extinction as a nature conservation method. IUCN (2016) explains the potential benefit of de-extinction through the restoration of biodiversity, the enhancing of the ecosystem function and resilience and the technological advances for extant species. The framework by Seddon et al. (2014, p.141) is based on the 'restoration and enhanced resilience of ecosystems'.

However, several authors refute the fact that de-extinction will benefit nature conservation. For example, Bennett et al. (2017) explain that funding de-extinction projects and reintroducing extinct species can lead to a net biodiversity loss. They state that therefore, the decision to continue with de-extinction cannot be justified and based solely on grounds of biodiversity conservation. Cohen (2014) explains that if a de-extinct species becomes invasive, the species could form a hazard for the ecosystem. Banks & Hochuli (2017, p.393) argue that 'de-extinction is a dangerous idea for conservation' since de-extinction will undermine conservation efforts.

These arguments underpin the fact that, even though de-extinction is proposed as a nature conservation method, there are good reasons to suspect that the choice for candidate species is not solely informed by reasons related to optimal conservation outcomes. Dalrymple (2006) provides a framework that shows the relevance of social aspects in research (figure 1). This framework builds on insights in the field *Sociology of Scientific Knowledge* (SSK), which advocates that science is influenced by social aspects, and that developments in a scientific field are linked to a variety of political, historical, cultural, or economic factors (Shapin, 1995; Longino, 2019). More specifically, this builds upon the Social Construction of Technology (SCOT), which extends the ideas of SSK to technology development. Different actors shape the outcome of technology development with their interests, strategies and knowledge (Bijker, 2001; Olsen & Engen, 2007).

Dalrymple (2006) explains how priority setting is done in international agricultural research. The actors and their relationships that influence the decision-making of the researcher are identified. In terms of de-extinction research, this framework can be used to understand how and why the researcher's choice for a candidate species is shaped by different actors and their relations, and to interpret the data that is found. Since the original framework targets agricultural research, and not research on conservation biology, it needs to be adapted appropriately. The adaptations are explained below and the adapted framework can be found in figure 2.

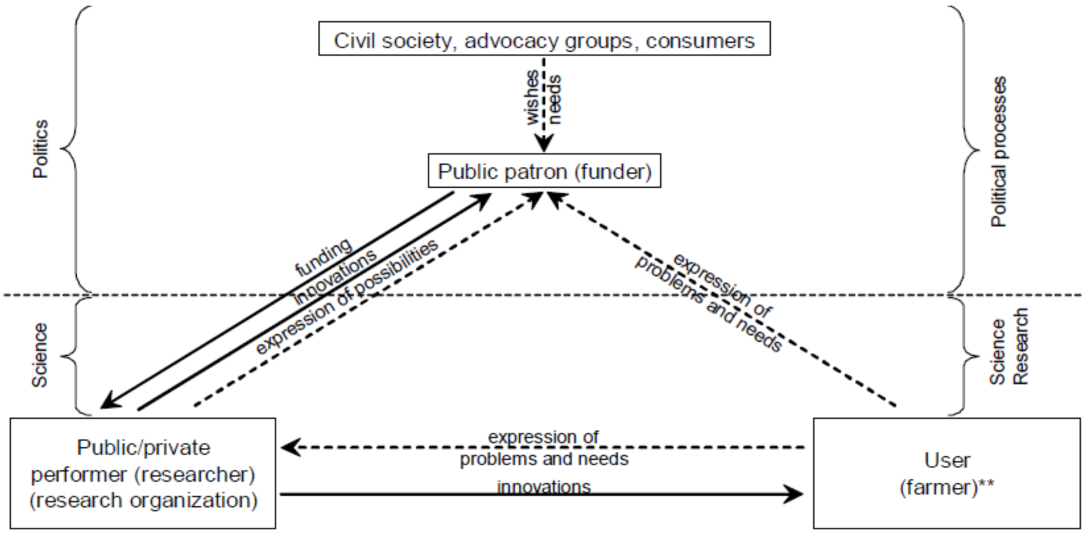

Figure 1: principle-agent theory framework adapted by Dalrymple (2006) to explain how actors influence priority-setting in international agricultural research

First, the researcher's priority setting is influenced by civil society, advocacy groups, and consumers. How the research topic, in this case the de-extinction candidate, is valued by the public, can influence the decision-making of all actors. The notion that public value has a strong influence on scientific research is supported in the literature (Pavitt, 1998), and there are indications that this is also the case for de-extinction research (Turner, 2017). Public value seems to be high for human-induced extinctions since a large part of the public experiences guilt and regret towards losing these specific species. This seems to influence the researcher in selecting a candidate species (Sandler, 2017). The public also seems to highly value species that are 'cool' or charismatic, which is thought to steer the researcher towards selecting charismatic candidate species (Kasperbauer, 2017). An example of a de-extinction candidate that fits these boxes is the Thylacine. This carnivorous marsupial is seen as the most iconic Australian extinct animal and one of the primary examples of human-induced extinction on the Australian continent. This species is highly valued among the public (Banks & Hochuli, 2017). This shows that the priorities of other actors may be shaped by public value (Ciarli & Ràfols, 2019). Since for the case of de-extinction it seems to be more the overall public value than individuals that may influence the decision-making, this box is renamed 'Public value'. In the original framework, public value was only connected to funders. However, the current literature gives clear indications that public value also directly influences researchers as well as users.

Second, the box 'Public patron (funder)' is about the funding of the project. Funders can have a big influence on research priorities of researchers, and is therefore seen as an important determinant in innovation (Vanloqueren & Baret, 2009). Since most de-extinction research requires capital investments, research on resurrecting a species can only work if the funder is willing to finance it. Funding for de-extinction research may not only come from public funding, but can also be given through private funding or other funding bodies. To include all the different funding possibilities, this box is renamed 'Funder'.

Third, the box 'public/private performer (researcher) (research organisation)' represents the researcher itself, which is the central actor that is influenced by the other actors in the framework. The researcher expresses the possibilities to the funder, as the researcher is limited by what is technological feasible. Cloning, for example, is only possible with fully preserved cells. Another example is that for genome engineering, the researcher has to be able to obtain enough viable DNA, which can be difficult for a very old species, since DNA decays over time (Novak, 2018; Shapiro, 2015b). IUCN (2016) mentions that developing the technologies for de-extinction could help extant species, because this would also bring technology development in broader conservation areas. Next to this, the researcher may have personal reasons for pursuing de-extinction of the specific candidate. As Bijker (2001) explains, social factors can influence the development of a technology. Therefore, personal reason must also be taken into account. To include all researchers in this box, it is renamed 'Researcher'.

Fourth, the so-called 'users' are represented in the last box: 'User (farmer)'. The user is affected by the species becoming de-extinct. This can be an individual, or a group of people living in the area where the candidate species would be reintroduced. In the case of de-extinction, this could for example refer to socio-economic benefits that could be achieved by de-extinction (IUCN, 2016). This could have positive impacts on the community through increased employment in, for example, tourism, or enhanced ecosystem services. The expectations of the user can shape progress in the technological field, and thus influence the character of the innovation (Oudshoorn & Pinch, 2003; Dosi & Nelson, 2013). This way, the community could have an influence in the decision-making by expressing their problems and needs to either the funder or the researcher. In the adapted framework this box is named 'User'.

This leads to the adapted framework that is shown below in figure 2. It illustrates that the priority setting is not studied by only looking at researchers and their individual preferences, but by studying priorities as the outcomes of interactions between different actors. Each actor can constrain and enable particular priorities in decision-making to be set.

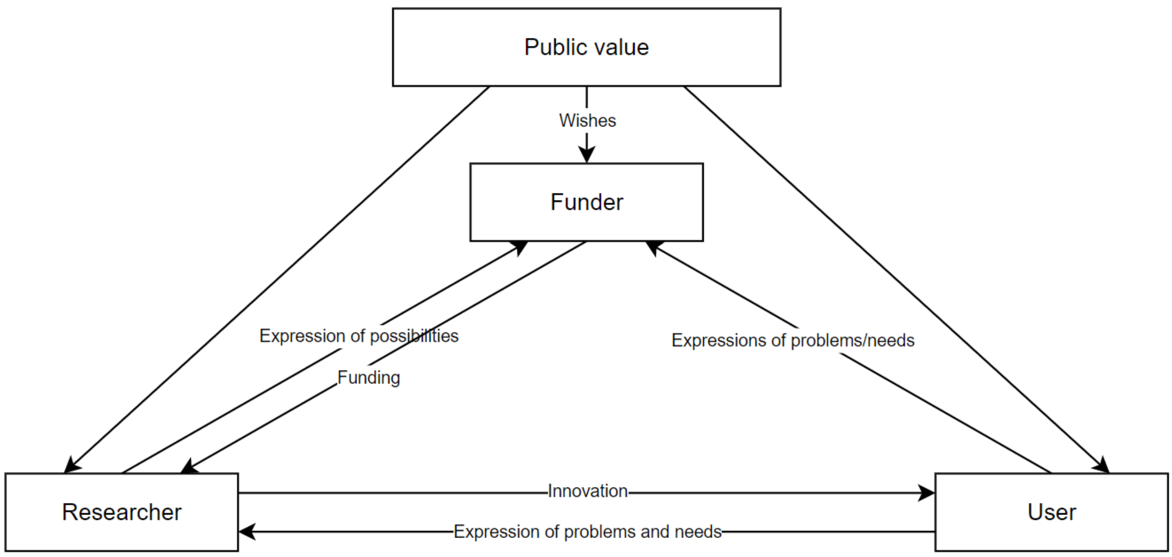

Figure 2: Framework to identify and explain (the relation between) the different actors, adapted from Dalrymple (2006)

Methods

This thesis attempts to answer how candidates are chosen by studying the priority-setting process in de-extinction *projects*.

These projects were selected using the following definition of 'a project': 'A project is a concrete and organized effort that leads to the realization of a unique and innovative deliverable, which can be (…) a science research initiative, which is conceived based on a perceived opportunity.' (Mesly, 2016). This means that some de-extinction initiatives were excluded from this research. An example of this is the Dodo. Revive & Restore has started a science research initiative with researchers on Mauritius, which is the natural habitat of the Dodo. However, so far this has led only to conversations and this is not yet a concrete and organised effort (Novak, 2016). Therefore, the dodo de-extinction does not comply with the definition of a project as stated above, and was hence excluded from this research. Some other initiatives by Revive & Restore, such as the Woolly Mammoth-, Passenger Pigeon-, and Heath Hen de-extinction, do comply with the above definition of a project and were thus included in this research. All three projects are concrete and organised efforts and researchers are working towards a determined deliverable.

To be able to stick to a clear set of de-extinction projects, a moment in history had to be set that marks the start of contemporary de-extinction projects. The Quagga back-breeding project, which started in South Africa in 1987, was taken as the first de-extinction project in this research. The Quagga, which is a subspecies of the Plain Zebra, was the first extinct animal to have its DNA (partly) sequenced, which marked the start of a new science. Moreover, the quagga project is said to be one of the inspirations for Michael Crichton's *Jurassic Park* (Heywood, 2013). This movie, which aired in 1993, was a turning point in public interest and DNA research. *Jurassic Park* caused a 'huge media splash' that led to more publications, grant funding, and a new generation of scientists (Botkin-Kowacki, 2018). Jones (2015) states that this development 'really does stem back to Jurassic Park. It is still the legacy of that. That's when it entered the public consciousness'.

As a primary data source, semi-structured and structured qualitative interviews were done to obtain information about the factors influencing the choice of candidate species. This qualitative approach through interviews is the best method for understanding the priority-setting process as identified in the theoretical framework. The fact that interviews were used as a data source also posed some limitations, such as the risk of people not responding, or not being willing to participate in the research. To overcome this, and to make sure that there was at least one respondent for every project, multiple researchers were contacted for every project. In total, 29 people were contacted, which resulted in eighteen interviews. Sixteen semi-structured interviews were done through Google Meet and Zoom, and two structured interviews were held over e-mail. The interviewees consisted of fifteen researchers and three (potential) users. To identify the interviewees, first, purposive sampling, in which particular persons are selected to provide specific information (Taherdoost, 2016), was done to contact all scientists that are leading, or working on, the de-extinction projects. More researchers and potential users were identified through snowball sampling from the interviewees. Since the interviews were structured and semi-structured, an interview guide was made prior to the interviews. The first part of the interview contained broad questions. After that, more in-depth questions were asked along the lines of the theoretical framework by Dalrymple (2006). Last, questions were asked about factors that are discussed by IUCN (2016) and Seddon et al. (2014). Follow-up questions were asked depending on the answers of the interviewees. The interview guide did increase the reliability of the research, but different follow-up questions could lead to different answers, and thus different data. This is a limitation that could not be fully overcome by using an interview guide. The interview guide is provided in Appendix I, and an overview of all interviewees is provided in Appendix II.

As a secondary data source, extensive literature research was done. All literature that had already been collected in earlier stages of the research was re-read and assessed to see what literature was still relevant. Also, additional literature was searched for in a systematic way. All webpages on Google page 1 were assessed for all searches. First, four different keywords for de-extinction were searched for: ‘de-extinction’, ‘species revival’, ‘species resurrection’, and ‘resurrection biology’. Second, these keywords were all combined with the names of the candidate species. Third, through *archive.org* the official websites for the de-extinction projects were visited on three points in time: when the website first appeared, between the first appearance and the current date, and the current website. Fourth, the keyword ‘de-extinction’ in combination with the different candidate species was searched for using the ‘advanced search’ option in Google, only enabling results from the country where the research is happening. In total, 128 online sources with relevant information were included, next to data that was obtained from the interviews.

All interviews were transcribed, and the interviews and literature were coded. Microsoft Excel was used to gather and code the data in a consistent way. First, motives that were mentioned by researchers for choosing their de-extinction candidate were identified from the interviews. This resulted in a list of motives that apply to multiple de-extinction projects. For example, one project is about bringing back an indicator species, while another project aims to reintroduce a keystone species. Both projects were labelled under the motive ‘ecological restoration’. The quotes that explain the motives were added in the Excel database to provide a clear overview. Next to that, the specific quotes were coded into more general findings, which made it possible to make comparisons amongst projects, from which patterns could be identified. For example, two interviewees from different projects can explain the importance of their species for its ecosystem in a different way, but the function of both species is the same. Both quotes were then coded, for example: ‘keystone species – ecosystem engineer (herbivory)’.

The framework that was adapted from Dalrymple (2006) (figure 2), was used to interpret the findings. The actors and the relationships that are mapped in the framework were used to explain how the decision-making of the researcher is influenced by those actors and what this means for the process of selecting a candidate species. The fact that this research is based on existing literature and a theoretical framework, increased the validity of the research. Together, the list of motives in combination with an explanation using the framework, provide a rich and complete answer to the research question.

Results

In total nine different de-extinction projects are identified since 1987. The species of these projects are listed in table 1.

Table 1: An overview of the studied de-extinction projects with their characteristics (Born to be Wild, n.d.; Choi, 2009; Galapagos Conservancy, 2017; Geggel, 2020; Hough, 1933; Hung et al., 2014; Monks, 2017; Passenger Pigeon Project, n.d.; Pickrell, 2017; What is a Quagga, 2021; The Tauros Programme, n.d.; Woolly Mammoth Revival, n.d.; Yong, 2013).

Species	Extinction date	Original habitat	Extinction cause	Project start	De-extinction technique	Project leader
Quagga	1883	South Africa	Hunting	1987	Back-breeding	The Quagga Project
Pyrenean Ibex (Bucardo)	2000	Iberian Peninsula, Spain	Hunting	1999	Cloning	Agro-Nutrition Research & Technology
Floreana Island Giant Tortoise	±1850	Floreana Island, Galapagos	Hunting	±2000	Back-breeding	Galápagos National Park Service
Gastric Brooding Frog	1982	Queensland, Australia	Unknown, maybe human introduction of Chytrid fungus	Early 2000's	Cloning	University of New South Wales
Auroch	1627	Asia, Europe, North Africa	Habitat loss & hunting	2008	Back-breeding	Tauros Project, True Nature Foundation
Thylacine (Tasmanian Tiger)	1936	Australia, Tasmania	Hunting	2008	Genome engineering	University of Melbourne
Passenger Pigeon	1914	North America	Hunting	2012	Genome engineering	Revive & Restore
Heath Hen	1932	North-eastern US	Hunting	2014	Genome engineering	Revive & Restore
Woolly Mammoth	±3900yrBP	Northern steppes	Low genetic variety, reduced food sources due to warmer weather, isolation, habitat loss	2015	Genome engineering	Revive & Restore, SOOAM Biotech Research Foundation

These projects vary on many different levels. There are different kinds of species. There are four mammals (the Quagga, Auroch, Pyrenean Ibex and the Woolly Mammoth), one reptile (the Floreana Tortoise), one amphibian (the Gastric Brooding Frog), two birds (the Passenger Pigeon and the Heath Hen) and one marsupial (the Thylacine). The projects are done in many different parts of the world, ranging from South Africa and Australia to the United States. However, de-extinction is targeted most in Western countries. Also, all three possible techniques are used in these projects. The Auroch, Floreana Tortoise and Quagga are revived through back-breeding. De-extinction of the Pyrenean Ibex and the Gastric Brooding Frog is attempted through cloning, and the Passenger Pigeon, Woolly Mammoth, Heath Hen and Thylacine de-extinction rely on genome engineering. The projects are carried out by different research institutes. Revive & Restore is a primary organization within the field of de-extinction research and is working on three of the genome engineering projects, namely the Passenger Pigeon, the Woolly Mammoth and the Heath Hen. For all three projects they work together with universities to facilitate the research. Some projects are executed by researchers from a single university, namely the Thylacine research and the Gastric Brooding Frog research. Then there is also a National Park Service facilitating research for the Floreana Tortoise, which is also working together with universities. For the back-breeding project of the Quagga, a whole new foundation was established, called The Quagga Project.

It is clear that the projects vary greatly in their type of species, the de-extinction techniques and the research body. One characteristic, however, that all projects share, is the role humans played in the extinction of the species. For all projects, mankind is thought to have played a key role in the extinction, through hunting, habitat loss or the introduction of invasive species.

Motives for species selection

After having done eighteen interviews with researchers and other people involved in the projects, as well as an extensive literature review, seven motives were mentioned by researchers to choose a particular species for their de-extinction research. Among those motives are three ecological reasons, namely ecosystem restoration, the restoration of biodiversity, and technology development for saving endangered species. Four other motives are possible human medical implications, personal reasons, the responsibility to correct human mistakes, and the charismatic status of the candidate species.

For all projects, more than one motive was found to play a role in the researcher's choice. The motives are summarised in table 2, and are elaborated on below. The motives are discussed in the order from most mentioned to least mentioned.

Table 2: A brief overview of all motives that were found to play a role in species candidate selection for de-extinction projects, with a short explanation.

Motive	Explanation	Projects where this motive played a role
Charismatic status	For all candidate species the iconic status was mentioned as a motive, ranging from the animal being charismatic, culturally important or unique.	(All projects) Quagga, Auroch, Floreana Island Giant Tortoise, Passenger Pigeon, Woolly Mammoth, Heath Hen, Gastric Brooding Frog, Pyrenean Ibex, Thylacine
Correct human mistakes	Humans are thought to have caused the extinction of all candidate species through hunting, habitat loss or the introduction of invasive species.	(All projects) Quagga, Auroch, Floreana Island Giant Tortoise, Passenger Pigeon, Woolly Mammoth, Heath Hen, Gastric Brooding Frog, Pyrenean Ibex, Thylacine
Technology development	Developing the technology necessary for de-extinction can also benefit endangered species and help in conservation efforts.	(All cloning- and genome engineering projects) Passenger Pigeon, Woolly Mammoth, Heath Hen, Gastric Brooding Frog, Pyrenean Ibex, Thylacine
Ecosystem restoration	By reintroducing the keystone- or indicator species that went extinct, the natural balance in the ecosystem could be restored.	Auroch, Floreana Island Giant Tortoise, Passenger Pigeon, Woolly Mammoth, Heath Hen, Thylacine
Restoration of biodiversity	Simply by having the species back, a bit of the biodiversity that was lost will be restored.	Floreana Island Giant Tortoise, Woolly Mammoth, Pyrenean Ibex, Thylacine
Medical implications	The characteristics of these species have the potential to benefit human medicine if further explored.	Floreana Island Giant Tortoise, Woolly Mammoth, Gastric Brooding Frog
Personal fascination	The personal reasons vary from a personal obsession with the species to academic curiosity.	Quagga, Passenger Pigeon, Gastric Brooding Frog

Charismatic status

First, one motive that was mentioned for all projects is the charismatic status that the species has. This does not come as a surprise, since the influence of animal charisma on conservation efforts has been widely studied and recognised in the literature. Jarić et al. (2020, p.345) define animal charisma as 'a set of characteristics – and the perception thereof – that affect people's attitudes and behaviours toward a species'. Examples of those characteristics are a unique morphology, symbolic characteristics that have cultural importance, or visual charisma such as a large body size and a high 'cuddle-factor' (Jarić et al., 2020; Turner, 2017; Small, 2011). These characteristics are mostly found in large mammals and other terrestrial species, which are therefore most perceived as charismatic (Albert et al., 2018).

These are exactly the type of species that are candidate species in the de-extinction projects. From the nine projects, most species are mammal, and all species except the Gastric Brooding Frog are terrestrial. This focus on charismatic species in de-extinction research is also recognised in the literature. Kasperbauer (2017) argues that the existence value, valuing the fact that a species exists, is higher for charismatic species, and that this is a main factor in de-extinction proposals. Turner (2017) also recognises that animal charisma can influence the selection of de-extinction candidates. It seems that, since all candidate species have some kind of charismatic trait, animal charisma is a requisite for a candidate species to be selected.

Three different characteristics were mentioned for the species being charismatic, and some species had multiple characteristics. First, an aesthetic, charismatic value was mentioned for the Quagga, Auroch, Heath Hen, Woolly Mammoth, and the Passenger Pigeon. A good example is the behaviour of the Heath Hen: 'You've probably seen the mating dance the Heath Hen do, and the booming call. Those are things that are kind of attractive and noteworthy.' (Interview Chase, 23 March 2021). Second, the Auroch, Floreana Tortoise, Passenger Pigeon, Heath Hen, and Thylacine are charismatic because they are so iconic. All of these species have historical and cultural importance. A good example of this is the Auroch: 'The Aurochs is the ancestor of all cattle and thereby the most important animal in the history of mankind.' (Born to be wild, n.d.). Third, the Thylacine, Gastric Brooding Frog and the Floreana Tortoise are charismatic because they are so unique. The Thylacine, for example, 'was a very, very unique marsupial species. The last one of its kind. That uniqueness is exactly why we might want to bring it back to life. Our continent could once again be host to one of Australia's most iconic lost species.' (Whigham, 2018).

Responsibility for correcting human mistakes

Second, the only other motive, next to animal charisma, that played a role in all projects is the responsibility that researchers feel for correcting human mistakes. All candidate species went extinct (or are thought to have gone extinct) primarily due to human causes, such as hunting, habitat loss and the introduction of invasive or domestic species. In fact, undoing this mistake is the only goal of the Quagga project: 'the goal is to try and reintroduce an extinct subspecies (…) to central South Africa because it shouldn't have happened. It was a pointless and useless and silly thing. (…) Well, it was lost by South Africans. And bloody hell, South Africans are going to bring it back.' (Interview Turnbull, 4 March 2021).

This feeling of responsibility is in line with the development of human's role in nature over the years. For ages, before the emergence of conservation biology, humans did not feel responsibility for nature and biodiversity (Soulé, 1985; Oksanen, 2007). With the emergence of the field of conservation biology, the belief that humans have a responsibility to foster biodiversity has grown. Nowadays, human's role in the global loss of biodiversity is widely recognised and 'best characterised by individual action and collective inaction' (Oksanen, 2007, p.181).

The feeling of responsibility also finds expression in the motivations in de-extinction research. Jebari (2016) argues that humanity has a collective responsibility to reduce the harm that is created with the anthropogenic extinction of species. Therefore, humans have the moral obligation to revive the species if this becomes possible. However, arguably it would be difficult for researchers to choose a species whose extinction was not man-made, since 'natural extinctions, however, are rare events on a human time scale. Of the hundreds of vertebrate extinctions that have occurred during the last few centuries, few, if any, have been natural.' (Soulé, 1985, p.730).

There seems to be a correlation between the feeling of guilt towards a species' extinction and the level of charisma. A man-made extinction seems to give the species a higher level of charisma. The Passenger Pigeon became an icon of conservation after it became extinct: 'The conservation movement itself formed in response to the extinction of the Passenger Pigeon. When the last birds were shot in the wild, mere decades after their population numbered in the billions, their absence from the skies demonstrated that even the most abundant of natural resources could be exhausted by unchecked human consumption, beginning a new age of conservation regulation and game management' (Passenger Pigeon Project, n.d.). Vice versa, the feeling of guilt seems to be higher for charismatic species that go extinct. Lorimer (2007) explains that charismatic species trigger strong emotional responses and sympathetic affections in humans. Because the feeling of guilt is thus related to the level of charisma, this alone cannot be seen as a requisite condition for species to be selected.

Ecosystem restoration

Third, ecosystem restoration is one prominent motive for selecting particular species in all projects except for three of the first de-extinction projects, namely the Quagga project, the Pyrenean Ibex project and the Gastric Brooding Frog project. Researchers motivated their choice of species by pointing to the key role that their species plays in maintaining a particular ecosystem. This is also known as 'keystone species', which are 'species that maintain the organization, stability, and function of their communities, and have disproportionately large, inimitable impacts on their ecosystems' (Hale & Koprowski, 2018, p.439). When such a keystone species goes extinct, the ecosystem becomes unstable and threatens the existence of other species living in that ecosystem. By reintroducing the keystone species into its environment, the researchers hope to restore the natural balance in that ecosystem. The Auroch, Floreana Tortoise, Passenger Pigeon, Woolly Mammoth and Thylacine are said to be such keystone species. The Auroch, for example, 'was one of those big grazers that had a profound impact on its environment. (...) They maintain the open ecosystems and thus create a suitable environment for many other species as well. They are the base of the European biodiversity. That is our primary reason for doing this.' (Interview Goderie, 15 March 2021).

Next to keystone species, the important role of indicator species in ecosystem restoration was mentioned. An indicator species is used to represent the health of its ecosystem. It provides data that is representative for the whole ecosystem, which is more efficient than gathering data for all aspects of the environment separately (Bal et al., 2018). The Heath Hen, for example, could possibly fulfil that role: 'My understanding is, is that it's for the most part an indicator species of natural health, of the surrounding environment. I do think that if you have a species that can support itself within the environment that it came from, it does give you an indication of the health of the land around you.' (Interview Walzem, 4 March 2021).

Ecosystem restoration as a motive is related to the desire to correct human mistakes, since anthropogenic factors are mostly the ultimate driver of keystone species decline nowadays (Hale & Koprowski, 2018). For example, one researcher working on the Floreana Tortoise project would not try to revive this keystone species if it was a natural extinction: 'If it was an extinction, a natural process of extinction, then they're gone, you can't just bring them back if and I don't think there is any reason if there was a natural extinction of some sort. But here in this case, they were fine without us mingling with them. So there's also some sort of ethical, I think for me at least, it's also sort of moral imperative.' (Interview Caccone, 1 March, 2021).

Before the revival of keystone- or indicator species, the first de-extinction projects were initiated only for reviving the species itself. Only in later projects, de-extinction of a species is used as a method to restore the ecosystem it lived in. For example, The Gastric Brooding Frog as one of the earliest candidate species, was not chosen for its ecological importance: 'I guess the primary importance of that one is simply the stunning ability of that frog to manipulate how it manages its internal organs. So there are other things there that are going to be important.' (Interview Archer, 18 February 2021). This shift is consistent with a broader shift that is seen in the field of nature conservation. The classical view on ecology and conservation biology is one that focused on an isolated target species. Pickett et al. (1992) argued that conservation 'above and beyond the species level' must become the new norm in conservation, and that the focus has to be on understanding the process and context within the ecosystem, rather than focus on the conservation on species level. They explained the difficulty of spreading this new view, since the classic species-focused view was still widely recognised. At the end of the 1990s, the need for ecosystem-level management rather than the traditional management that is focused on individual populations and species was still there, but the execution was still rather difficult.

This gave rise to the concept of 'keystone species', that plays such a prominent role in the species selection for de-extinction. Single-species management and ecosystem management were combined into the management of keystone species, with the hypothesis that 'if the keystone affects many other species in its community, it may well be that facilitating its growth and reproduction would support the many species it interacts with as well.' (Simberloff, 1998, p.255). Keystone species conservation and reintroduction as a broader conservation tool was completely absent prior to 1995 and has grown more popular while the necessity for reintroduction of keystone species as a conservation tool increased (Hale & Koprowski, 2018). Seddon et al. (2007) describe this growing attention for reintroduction projects as a now recognizable field of reintroduction biology. Reintroduction projects aim to bring back species to areas where they have gone extinct. The number of keystone reintroductions more than doubled between 1998 and 2005. Therefore, the shift from species-level de-extinction, which was the idea for three of the earliest de-extinction projects, to bringing back keystone species to preserve the whole ecosystem, is a logical development in this field of nature conservation.

While ecological restoration was a motive for choosing de-extinction candidates in six out of nine projects, ecological restoration on itself cannot fully explain the choice for a particular species. There are many other, less charismatic keystone species that are going – or already are – extinct due to human activity, that are not the focus of any conservation- or de-extinction project. An example of this is the mite. Mites play key roles in many different ecosystems all over the planet, and they ensure the existence of floristic diversity, habitat complexity and insect diversity. It is estimated that by 2000, 15% of all mite species had already gone extinct, and this number is rising. Humans are said to be responsible for this decline due to habitat destruction and degradation (Sullivan & Ozman-Sullivan, 2021). Yet, this keystone species has not been the focus of any conservation- of de-extinction project for the past decades.

Technology development

Fourth, technology development was found to be a motive for all projects, except the three back-breeding projects, who are solely focused on bringing back the animal they are working on. The researchers of the Passenger Pigeon, Woolly Mammoth, Heath Hen, Gastric Brooding Frog, Pyrenean Ibex and Thylacine believe that the technology can also benefit endangered species and help in conservation efforts. Reviving the species is thus not the only objective of these projects, but also creating the tools and technologies. The researchers think that de-extinction is a good field for developing these tools, because de-extinction itself, as well as the species they are working on, draw worldwide attention. For one of the researchers working on the Woolly Mammoth, this is one of the main reasons: ‘It would create a general pipeline to using synthetic biology and engineering tools to preserve species and maybe bring some of the species back.’ (Interview Hysolli, 9 March 2021). For the lead researcher of the Thylacine project, Andrew Pask, technology development is the most important short-term focus: ‘All of those technologies have immediate conservation benefits for marsupials right now, as well as paving the way for the Thylacine de-extinction later.’ (Interview Pask, 4 March 2021).

Although technology development is mentioned as a motive for all projects that use cloning or genome editing techniques, it is not likely to be a requisite in choosing a species candidate. This is because technology development can happen when working on any species, but still only charismatic, extinct species are chosen for this. More and more research is being done into the use of genome editing and CRISPR/Cas9 technology for saving endangered species. Piaggio et al. (2017) provide two examples for this: One is the eradication of invasive rodents on islands by editing the chromosomes, resulting in only male offspring. Another is the use of synthetic biology to suppress avian malaria, which is carried by mosquitoes and is responsible for significant bird extinctions on the Hawaiian Islands. This shows that technology development also has potential when performed on extant, non-charismatic species.

Restoration of biodiversity

Fifth, the restoration of biodiversity was mentioned as a motive for the Thylacine, Pyrenean Ibex, Woolly Mammoth, and the Floreana Tortoise. Simply by having the species back, a bit of the biodiversity that was lost will be restored. For the Gastric Brooding Frog project, this is one of the primary drivers: 'I was particularly focused on the issue of biodiversity. I'm pretty fanatical abdicate about the importance of maintaining as much of the global genome, the distinctive parts of the global genome, as possible. This represented a big chunk that was otherwise was going to be subtracted from the world.’ (Interview Archer, 18 February 2021).

This motive on itself cannot explain the decision-making process regarding species selection, since the revival of any extinct lineage of species would result in a more diverse fauna. Nevertheless, only charismatic species are selected. One example of a recently extinct genus is Boromys, a genus of Cuban rodents. Boromys contains two species that both went extinct after the 16th century (Borroto-Páez et al., 2017). This, and many other less charismatic genera are not targeted for de-extinction research.

Medical implications

Sixth, another motive that plays a role in species selection is possible human medical implications. Some candidate species have features that may potentially benefit human medicine. Some researchers believe that Mammoth haemoglobin may reveal useful information for human medicine (Woolly Mammoth Revival, n.d.), and studying the long-lived Floreana Tortoises may reveal useful information in oncology research, since they do not develop cancer (Interview Caccone, 1 March 2021). The Gastric Brooding Frog could give insights in managing gastric secretions. One researcher noted that ‘trying to understand that, some biologists thought would be, you know, give us clues on how to control those problems in humans like gastric reflux and various things. So it was quite an important medical model' (Interview Mahony, 21 February 2021). Reviving these extinct species might lead to advances in human medicine.

However, medical implication as a motive does not seem to be a requisite in species selection. Many species that did or could function as medical models are not charismatic, and are not chosen for de-extinction projects. An example of this is the Chinese bahaba. This is a large fish whose swim bladder was used for the prevention of miscarriages in Asia. This fish was declared virtually extinct in 2001 (Courchamp et al., 2006). However, only medical models that are charismatic are targeted for de-extinction projects.

Personal fascination

Last, personal fascination was mentioned as a motive in five projects, namely the Quagga, Passenger Pigeon, Heath Hen, Gastric Brooding Frog and the Thylacine. Those personal interests vary greatly. For Eric Harley, lead scientist for the Quagga Project, it was more about the 'interesting puzzle' than the animal: 'Other people are more concerned with getting the Quagga back, restoring this variety which had been shot out. And I mean, yes, I agree with that, but mine was more the academic curiosity.' (Interview Harley, 4 March 2021). For Ben Novak, the lead scientist on the Passenger Pigeon, his personal fascination was most important: '"I am a very, very passionate Passenger Pigeon enthusiast," Novak told me. "There are people in the world who love pigeons. And within that group there are people who become life-long obsessives with the Passenger Pigeon. I fell into that group when I was very young."' (Mark, 2013). Novak also stressed that 'one of the big reasons that any species is picked for a de-extinction effort is that the person who wants to work on it is passionate about that species (…). For a project that's going to take 20 to 30 or 40 years from start to finish, you have to be passionate to keep going.' (Interview Novak, 19 February 2021). Next to scientific curiosity and a passion for the species, Michael Mahony has another personal reason for wanting to revive the Gastric Brooding Frog: 'I had another personal reason for wanting to work on this frog. I discovered the second species. So when it went extinct, I was sort of like a I suppose, a personal loss of some sort. I don't know too many biologists who have described a species that's now extinct.' (Interview Mahony, 21 February 2021).

This motive does not come as a surprise. Even though in the past research was seen as a solely objective and rational practice, nowadays it has become more acknowledged in the literature that 'personal interest might lead the researcher to research certain topics and phenomena', and that 'the personal context helps you understand the motivation for the research.' (James & Vinnicombe, 2002, p. 85 & 86).

Although personal interest may be important in persevering with the research, it does not seem to play a requisite role in species selection. This is because there are many non-charismatic species or genera that are the topic of personal fascination for many researchers, that are not chosen for conservation projects. An example of this is the jellyfish and other gelatinous species, which are a topic of great interest for many marine biologists and ocean scientists. This fascination is shared during the Jellyfish Bloom Symposium, an international event that has been held six times so far and aims to share current and future research on jellyfish (Hugot, n.d.; 5th International Jellyfish Bloom Symposium, n.d.). However, non-charismatic species that are the topic of personal interest are absent on the de-extinction candidate list.

In total, seven rather diverse motives are found to play a role in the species selection for de-extinction research. Two important findings come from reviewing these motives.

First, the motives vary from ecological reasons such as ecological restoration, the restoration of biodiversity and technology development for conservation benefits, to more humanistic reasons such as human medical potential, personal interest, human guilt and animal charisma. This finding strongly departs from existing literature on how candidate species should be selected. The three ecological motives comply with the proposed benefits written by IUCN (2016), who stress that any de-extinction can only be considered from a conservation viewpoint, and that the revival of any extinct species should have a considerable conservation or ecological benefit. However, the guidelines from IUCN exclusively focus on ecological- and conservation benefits, and do not leave room for the four humanistic motives. Another framework on species selection is provided by Seddon et al. (2014), who propose a 'De-extinction candidate selection and translocation flowchart'. They assume that the species selection is principally driven by a perceived conservation benefit, although they also include public attitude and technical feasibility as influencers of de-extinction candidate lists. However, both frameworks do not leave room for personal interest, animal charisma, or human guilt. The human medical potential is even explicitly mentioned by Seddon et al. (2014) as not being a driver in the process of species selection.

Second, despite the large variety of motives, two motives were found to play a role in all projects: the charismatic status of the species and the extinction to be caused by humans. This is a remarkable finding because when various motives play a role in species selection, one would expect different kinds of species to be selected based on the different motives. However, this is not the case, since only charismatic species that went extinct by humans are targeted. The preference for species that went extinct by humans can be explained by its correlation with animal charisma as is elaborated on above. Also, it would be difficult to find a recently extinct species that did not go extinct due to mankind (Soulé, 1985).

Although all motives are important and relevant in the species selection, animal charisma seems to be an essential condition for any species to be selected as a de-extinction candidate. For example, for ecological restoration there is a large pool of keystone species to choose from. Still only charismatic species are targeted, and non-charismatic species such as the mite are ignored. Another example is the potential to benefit human medicine. Human medical benefits can be found in many now extinct species, such as the Chinese bahaba. Still only charismatic species are targeted. The same applies to the other motives. Therefore, it is safe to say that charisma is an essential condition in the selection process. This favouritism for charismatic species cannot be explained by any of the other motives, as could be done for the preference for man-made extinct species.

The preference of charismatic species over other species can be explained with the theoretical framework (figure 2). With this framework I show that the relationships between the relevant actors create an environment in which the researcher structurally favours charismatic species.

Explaining the importance of charisma

My framework suggests that research priorities, in this case the selected de-extinction candidates, are determined by the relations between researchers, funders, users, and the public value. In the case of de-extinction projects, as I will show, the actors interact in ways that structurally favour the selection of charismatic species over other species. Each of the actors created incentives or pressures for selecting charismatic species. While by themselves they do not preclude the possibility to select non-charismatic species, taken together they make it very difficult to choose non-charismatic species. Therefore the actors together help to explain the exclusive selection of charismatic species in de-extinction projects.

The funder, the researcher and the user are described separately to discuss how they influence each other, and how the public value influences them in the choice for charismatic candidate species.

The funder

The funder is one actor in this framework that helps to explain the choice for charismatic species. Three different types of funding were identified: government funding in the form of grants, philanthropy in the form of private donations, and self-funding. Many de-extinction projects are funded by multiple types of funding. The Auroch project, for example, is partly self-funded, but also uses subsidies from programs and foundations they work with. Next to that, they rely on private donations and profit from 'wild meat', which they sell from their excess animals (Interview Goderie, 15 March 2021). Other projects, such as the Passenger Pigeon, the Woolly Mammoth, the Heath Hen and the Gastric Brooding Frog, rely solely on private donations. For this, the species need to be charismatic, since charismatic fauna receive more funding than non-charismatic fauna (Thompson & Rog, 2019).

These charismatic species are used as flagship species, which means they serve as symbols to stimulate conservation awareness and action (Ducarme et al., 2013). A great example to illustrate this is the Passenger Pigeon project. This is the flagship project from Revive & Restore to gain more attention and support for de-extinction practices (Passenger Pigeon Project, n.d.). Ben Novak explained that for this flagship project, the Passenger Pigeon as a candidate species was the result of a conscious choice for an iconic species: 'He acknowledged that the Long Now Foundation is focused on the pigeon in part because it's attention grabbing and, well, fundable. "Our goal is to get people behind the goal of de-extinction," he said. "We had proposed doing proof-of-concept work in a way that would use two living rats and an extinct species of rat, because the technology is much farther along for the cellular work with those species. But few people really care to work on a rat for a subject like this."' (Mark, 2013). This shows that in order to get the projects funded, it is necessary for the researcher to choose a charismatic species to get enough attention and funding.

The Heath Hen project also shows this. Tom Chase, one of the initiators of the project, is primarily interested in bringing back the original environment on Martha's Vineyard. This happens to be the environment that was home to the Heath Hen, and this iconic bird has given him the opportunity to get attention and funding for this project: 'You would also have, frankly, an iconic species that people could rally around. So many of the rare species I talked about are very tiny plants or insects and things like that, which frankly, most people just don't get that excited about it, but a Heath Hen, especially bringing back an extinct bird, people get pretty darn excited about that.' (Interview Chase, 23 March 2021). These examples illustrate how the public value of a species influences the funder, which in its turn affects the researcher in his choice for a candidate species. If a species is valued as being charismatic, it is easier for the researcher to get attention and funding for his work.

The expression of possibilities of the technology from the researcher to the funder also helps to explain the choice for charismatic species. The Gastric Brooding Frog project, for example, is funded by two individuals. The prospect of new technological developments through SCNT in an extinct species encouraged them to donate to the project (Interview Archer, 18 February 2021). Receiving attention and funding for expressing and exploring the possibilities of these new technologies is easier for charismatic species. A great example of this is the Thylacine project. They received a government grant after years of self-funded research to work on their short-term goal, which is developing new technologies for marsupial conservation. The charismatic Thylacine is used as a flagship to receive public attention and funding for this goal: 'It's really great for community engagement, particularly because I always use it as a platform to talk about marsupial conservation and the kinds of genetic tools that we can develop now to really help preserve some of our really precious marsupials.' (Interview Pask, 4 March 2021). Since people are more keen to donate to technology development research when charismatic species are targeted, this public value affects the researcher in the selection of a candidate species.

The researcher

The researcher or research organisation itself is also an important actor that helps to explain the choice for charismatic species. The researcher plays a role in terms of technological feasibility and personal interest. Technological feasibility, first, has proven to be an important determinant in the choice for candidate species, since the researcher is limited by what is technologically possible (Novak, 2018; Shapiro, 2015b). All de-extinction projects on long-extinct species started later, since gene editing technology did not exist until then.

Furthermore, there are other, more emotional and personal reasons that drive the researchers. In the choice for a specific candidate species, personal interest seems to be important. In general, researchers seem to be more interested in charismatic species, since they are susceptible to animal charisma as a driver for selecting species candidates (Jarić et al., 2019). This personal interest is influenced by the public value, since there is a strong correlation between the interests and preferences of society, and research interests (Monsarrat & Kerley, 2018; Jarić et al., 2019). Therefore, researchers seem to be more interested in charismatic species that are highly valued by the public.

A clear example of this is the personal interest Ben Novak has for the Passenger Pigeon, as was already described in the previous chapter. The Passenger Pigeon was, and is still valued as a charismatic, iconic bird because of its huge flocks and unique social dynamic. Many recorded memories on the Passenger Pigeons exist and poetry is written about them (Yeoman, 2014). Novak got fascinated by the pigeon after reading these stories, and he became captivated by their iconic history and charismatic appearance (Interview Novak, 19 February 2021).

This shows that there is a combination of rational and emotional motivation that drives the researcher to his or her decision to work on a specific species. This motivation is driven by public value, which causes the researcher to focus on more charismatic species for de-extinction projects.

The user

The user can also help explain the choice for charismatic species. The user is the person or community that will be affected by the species becoming de-extinct. They can benefit from this de-extinction through increased income from tourism. Several studies have shown that charismatic species attract more tourism and thus generate more income for local communities than non-charismatic species (Bennett et al., 2015, Colléony et al., 2017; Skibins et al., 2013). Therefore, the benefit that the community receives will be higher for charismatic species. This benefit is necessary for getting the community actively engaged, which is important for all three back-breeding projects to succeed long-term. The reasons for this differ between the back-breeding projects, as do the ways the community is engaged.

In the Quagga project, farmers need to be willing to take on herds of Quaggas for grazing and extra feedings. This is necessary for the Quagga to grow in numbers, and create a viable herd that can eventually be released. However, in the end, the farmers also have to make a living off of their farm. The Quagga, with is charismatic appearance, has already proven to draw more tourists to the farms, which makes it more attractive for farmers to take on some of these animals (Interview Bester-Treurnicht, 10 March 2021).

For the Auroch project, farmers and other people living in the potential release area have to agree on the animals roaming on their land and surroundings. One researcher explains that 'it's mostly the ecosystems that will benefit from this program. But to make that happen, sometimes you have to organise in a way that also benefits people.' (Interview Goderie, 15 March 2021). To make this happen, the TaurOs programme and Rewilding Europe try to 'bring back not just nature, but also people back to the area in a way that is economically and financially sustainable' (Interview anonymised interviewee, 5 March 2021). True Nature Foundation, another organisation working on back-breeding the Auroch, explains that the charisma and iconic status of the Auroch helps to achieve this: 'the Aurochs is an iconic animal which is likely to attract visitors, if roaming free in natural herds, thus stimulating ecotourism.' (Interview Beauchez, 15 March 2021).

De-extinction of the Floreana Tortoise comes with challenges because there is a community living on Floreana Island, which also brings rats that will eat the tortoise eggs. One of the researchers foresees difficulties for the community with overcoming this challenge: 'the eradication of rats could lead to impacts on livestock or impacts on pets or other animals that will make life unpleasant, at least for the period in which rats are attempted to be eradicated.' (Interview Hunter, 23 February 2021). However, the return of tortoises to Floreana Island will boost the economy because more tourists will probably come to visit (Interview Hunter, 23 February 2021; Interview Caccone, 1 March 2021).

The influence of users on the selection of de-extinction species by researchers is affected by the public value. If a candidate species is highly valued by the public because of its charisma or iconic status, this draws more tourism and income for the local community. This incentivizes the community to become actively engaged, which is important for the success of the project. This helps to explain the importance of animal charisma in choosing a candidate species for de-extinction projects

These results show that all of these actors strongly favour charismatic species. Together, they interact in a way that ensures the researcher to structurally favour charismatic species as de-extinction candidates. Evidently, the selection of solely charismatic species for de-extinction projects is not a coincidence, but the result of the interaction between public value, funders, communities and the researchers.

Discussion & Conclusion

The conservation of nature and biodiversity is more important than ever, since scientists believe we are currently living in the Sixth Mass Extinction (Kolbert, 2014; Barnosky et al., 2011; Ceballos et al., 2015). This is not only harmful for biodiversity and nature in general, but also for human society, which relies on biodiversity for numerous good and services (Gamfeldt et al., 2008).

Nature conservation is increasingly making use of advanced technological innovations like those in synthetic biology. De-extinction is an emerging technology within this field and it is posed as an important possible solution for the mass extinction. With this technology, researchers will most likely be able to bring back extinct animals into the ecosystem. While a lot of research has been done into the possible consequences of de-extinction and the ethical questions surrounding it, empirical research on the choices concerning de-extinction candidates was lacking. However, this knowledge is important because the revival of different species will have different consequences for the ecosystem and society. It is essential to develop guidance and clarification on making the important decision on which species gets to be revived, so a conscious choice can be made. Therefore, this research answers the following question: *How are species candidates chosen in de-extinction projects?*

The research was performed on nine de-extinction projects that were identified since 1987. Based on eighteen interviews I discovered two main findings. First, many different motives were found for selecting de-extinction candidates. Three of those motives are ecological and adhere to the existing selection framework by IUCN (2016). Seddon et al. (2014) propose a selection framework based on ecological motives as well, but they also include public attitude as a potential motive. Although other motives that I found were mentioned in the literature, such as the responsibility to correct human mistakes (Sandler, 2017; Jebari, 2015), and animal charisma (Kasperbauer, 2017; Turner, 2017), they are not mentioned in the proposed frameworks on how candidates should be selected. Also, this thesis is the first to empirically study and discuss all motives, instead of only a few.

Second, I found that animal charisma as a motive plays a pivotal and conclusive role in selecting species for de-extinction. Therefore, charisma seems to be an essential condition in this selection process. Although this is a novel finding in the context of de-extinction, this favouritism for charismatic species has been recognised in the literature on the general field of nature conservation. Species that receive the most conservation attention are mostly large, charismatic species, and their conservation status seems less important (Small, 2011; Colléony et al., 2017). The influence of some actors on prioritising charismatic species for conservation has also been researched. It is known that the public value is higher for charismatic species (Skibins et al., 2013) and that the charismatic status outweighs the endangered status (Colléony et al., 2017). Since humans have strong biases that seem to determine preferences for specific species (Small, 2011), flagship species have been increasingly used as a source to generate funding (Bennett et al. 2015). The personal preference of researchers in nature conservation also seems to point towards either economically important species, or species they find interesting (Small, 2011). Small (2011) also mentions communities, but he only touches upon the possible negative consequences for those people. The opportunities that local people could get from collaboration in projects, such as increased income by more tourism, are not discussed.

These earlier research papers have all focused only on separate actors in nature conservation. Thereby the focus was not on de-extinction, nor has charisma been linked to other motives. Also, a clear understanding of the way the actors interact with each other, and the implications of that interaction, has been missing. I found that a more socially constructed view with the framework that was adapted from Dalrymple (2006) (figure 2) is very useful for this. It explains the favouritism of charisma as the outcome of interactions between researchers, funders, users and the public value.

This favouritism for charismatic species gives reason for concern, since conservation outcomes may not be optimal if the focus is on charismatic species only. Conservation management has known a shift from single-species management to ecosystem management – albeit through species such as keystones and indicators. This trend can only continue in the future if the focus of de-extinction projects moves towards keystone species, rather than charismatic species.

My framework helps to understand what measures can be taken to promote outcomes in the decision-making process that would better serve nature conservation purposes. This includes a more systematic understanding of the way priorities are set as the outcome of relations between different actors.

In order for research priorities in de-extinction projects to divert from selecting charismatic species, the relationships between all actors has to change. Together, the actors must create new circumstances in which it becomes possible for the researcher to make different choices. For example, it is necessary for users to profit from the de-extinction of non-charismatic species. If other ways of making profit are searched for rather than tourism, the charismatic status would become less important for the user. Next, it is important to change the public value of species. More education on endangered keystone species and less commercial focus on charismatic species as flagships could help divert the focus of the public to keystone species, as Simberloff (1998) proposed as a strategy to combine single-species management and ecosystem conservation. On the other hand, a species' charisma can be constructed by marketing strategies (Ducarme et al., 2013). This could give more (keystone) species a higher public value, which will positively affect the interest of the other actors. Changing the public value, or managing human biases, is the most important strategy in changing funding priorities. Another way to divert funding towards less charismatic species could be to have several independent people deciding on research priorities. This way, there is less risk of private funders steering the research in specific ways or subjects (Small, 2011). However, more research needs to be done into which changes will work best in different contexts, and whether other changes can also shift the focus to non-charismatic species.

My research provides clear and solid findings. The validity is high, since the interviews were based on existing literature, and on the theoretical framework. The reliability of the interviews could be improved though. Since most interviews were semi-structured, the responses of the different interviewees led to different follow-up questions. Under different circumstances, different follow-up questions could be asked, hence leading to possibly different results. One other limitation is the low variety of interviewees. Although a reasonable amount of eighteen interviews was conducted, these were mainly with researchers. Only a few users, and no funders were interviewed. Also, the public value was not determined through interviews with 'the public'. The literature research, however, has a high reliability because it was conducted in a consistent and systematic way, and every search was documented to ensure transparency. The generalisability of the research is also high. All de-extinction projects from 1987 onwards that were found, were included in the research. My research shows strong results that are applicable to all projects, and this resembles similar patterns in the larger field of nature conservation.

Overall, this thesis gives a first holistic insight in how species candidates are chosen in de-extinction projects, and how the relationships of the relevant actors play a role in the preference for charismatic species. To my knowledge, this is the first time that such a framework is used to analyse this. Also, this is the first research that combines empirical data from different de-extinction projects into one thesis. This is also relevant for understanding how the broader context of nature conservation will be shaped in the future. Overall, this theoretical clarification of the societal factors surrounding de-extinction will help all actors to make better informed decisions on why to raise the dead.

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Appendix I

Interview guide – Researchers

A. Shortly describe the purpose of the research
B. Ask permission for recording the interview
C. (Always ask for explanation/examples)

1. Can you tell me a little bit about this project?
    a. What are you doing exactly/what is your contribution?
    b. Who commissioned/started this project?
    c. What is the ultimate goal?
    d. Why do you think this is important?

2. Why/How did you decide to choose this particular species?
    a. Why de-extinct this species?
    b. Why were other species not chosen?
    c. Were you familiar with this species and what did you think about this species?
    d. What excites you about de-extinction of this species?
    e. Do you think these reasons can justify the act of de-extinction (for this species)?

3. Are you aware of the public opinion on this species?
    a. How is the species perceived by the public/society? (charisma, cultural value, symbolic importance, etc.)
    b. Does this public opinion help in this project? Why (not)?

4. How do you pay for the de-extinction research?
    a. Where do you get funding from? (Company/organisation/university etc)
    b. How was this funding arrangement established?
    c. What were the demands or conditions asked by the funders?

5. Who, would you say, benefits from this species becoming de-extinct? (People living in the area, the organisation that commissioned the research, funders, etc).
    a. Did they have any influence in this research?
    b. Did they have specific requests or thoughts about the project? (the species, the goal, etc.)

6. What are the boundaries of the technological possibilities?
    a. What technological limitations did you have to take into account?
    b. How did the technological feasibility affect your choice of a candidate species?
    c. Without any technological limitations, would you rather work on another species to de-extinct? Which species, and why?

7. Any last comments or questions?
8. Do you recommend any other researchers or relevant actors on this project I could talk to?

Interview guide – Users

A. Shortly describe the purpose of the research
B. Ask permission for recording the interview

1. Can you tell me a little bit about the project?
    a. What is the ultimate goal?
    b. Why do you think this is important?

2. (How) were you involved in the decision to start de-extinction on this species?
    a. Why de-extinct this species and not some other species?
    b. How will de-extinction of this species benefit you/the area/the organisation?
    c. Do you think these reasons can justify the act of de-extinction (for this species)?

3. Are you aware of the public opinion on this species?
    a. How is the species perceived by the public/society? (charisma, cultural value, symbolic importance, etc.)
    b. What does this mean to you? Could this have influenced your own opinion on the species, and the desire to de-extinct it?
    c. What would de-extinction of this species mean to you?

4. Did/do you have contact with the researchers and/or funders prior to- or during the project?
    a. How was this contact established? (who reached out to who?)
    b. Did you have any demands or conditions asked by the funders?
    c. Do you feel like your opinion and demands were included in the decision-making process of starting the project on this particular species?

5. Do you think de-extinction of this species is the best choice?
    a. Do you think this species should become de-extinct?
    b. If you could choose, without taking into account any (technological) limitations, would you rather see another species becoming de-extinct? Which species, and why?

6. Any last comments or questions?
7. Do you recommend any other researchers or relevant actors on this project I could talk to?

Appendix II

List of interviewees

Date	Interviewee	Project
18 February 2021	Michael Archer	Gastric Brooding Frog
19 February 2021	Ben Novak	Passenger Pigeon
21 February 2021	Michael Mahony	Gastric Brooding Frog
23 February 2021	Elizabeth Hunter	Floreana Island Giant Tortoise
1 March 2021	Adalgisa Caccone	Floreana Island Giant Tortoise
4 March 2021	March Turnbull	Quagga
4 March 2021	Rosemary Walzem	Heath Hen
4 March 2021	Andrew Pask	Thylacine
4 March 2021	Eric Harley	Quagga
5 March 2021	Anonymised interviewee	Auroch
9 March 2021	Eriona Hysolli	Woolly Mammoth
10 March 2021	Albé Bester-Treurnicht	Quagga
15 March 2021	Ronald Goderie	Auroch
15 March 2021	Guido Beauchez*	Auroch
17 March 2021	Charles Feigin	Thylacine
23 March 2021	Tom Chase	Heath Hen
27 March 2021	José Folch*	Pyrenean Ibex
31 March 2021	David Oehler	Passenger Pigeon

* These interviews were conducted through a structured list of questions sent over e-mail, since the interviewees were unavailable for an online meeting.