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UNIVERSITY OF TURKU

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From Current Challenges to Future Tools

Hanna Kalliolevo

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To Mother Earth
and all creatures
big and small

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ABSTRACT

World is facing an environmental crisis as biodiversity continues to decrease and ecosystems degrade at an alarming rate mainly because of global land use changes. Urgent actions are needed to prevent further losses and to start to restore already damaged nature. Biodiversity related compensations can be used to compensate for lost biodiversity values at one place with gained nature values at another place, but sometimes they are also used when a change in biodiversity causes economic or intangible loss to people. Ecological compensation is used to offset for the residual impacts on nature that development causes with the aim of net gain or no net loss of biodiversity. These compensations require extensive knowledge of the biodiversity values at the project sites. Biodiversity gains can be created by active restoration, but sometimes natural areas restore themselves passively. This is the case in rewilding which often means passively regenerating forests. Rewilding can also mean the reintroduction of certain key species such as large carnivores. Compensations can then be used to prevent and compensate for the damages that species cause on humans.

In this thesis, I studied current challenges of different types of compensations in preventing biodiversity losses from the perspectives of nature and people, and how compensations could support rewilding, i.e. habitat restoration and species recolonization. I found that Finnish biodiversity surveys done on the field are inadequate in their assessment of nature values and spatial considerations for offset purposes. Offsetting also relocates nature further from people in Australia which can cause an overall decrease of ecosystem services in urban areas and an increasing separation between people and nature. I also found that rewilding could be used as an inexpensive restoration method for creating biodiversity gains and reforesting England. Lastly, I suggested a new economic and participatory tool to fund for the prevention of wolf caused damages to people in Finland.

The contribution of this thesis is in the identified challenges of the compensation methods and how to overcome them by the suggested improvements to biodiversity surveys, and with a better consideration of local communities and ecosystem services especially in urban areas. The proposed new tools of using compensations for rewilding also provide potential for nature restoration and improved coexistence between people and other species.

KEYWORDS: Biodiversity offsetting, nature surveys, compensations, nature conservation, restoration, rewilding, no net loss, gray wolf

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TIIVISTELMÄ

Maailma on ympäristökriisissä. Luonnon monimuotoisuus vähenee ja ekosysteemien tila heikkenee nopeasti pääosin globaalin maankäytön takia. Tarvitaan nopeita toimia estämään luonnolle aiheutuvia vahinkoja ja ennallistamaan jo vahingoittuneita ekosysteemejä. Biodiversiteettiin liittyviä kompensaatioita käytetään korvaamaan menetettyjä luontoarvoja luomalla uusia luontoarvoja, mutta myös hyvittämään luonnossa tapahtuneen muutoksen aiheuttamia haittoja ihmisille. Ekologisessa kompensaatiossa luonnolle aiheutettuja vahinkoja yhdessä paikassa korvataan toisaalla niin, että biodiversiteetin määrä kasvaa tai ei ainakaan vähene. Tällöin tarvitaan mittavaa tietoa projektialueiden luontoarvoista. Aktiivisella ennallistamisella voidaan tuottaa luontoarvoja, mutta elinympäristöt voivat palautua myös itsestään, jos ne jätetään ennallistumaan. Metsien passiivinen ennallistaminen on villiinnyttämistä, jossa metsän annetaan kehittyä luontaisessa sukkessiossa. Villiinnyttämisellä voidaan tarkoittaa myös avainlajien, kuten suurten petoeläinten palauttamista tai niiden leviämisen edistämistä takaisin entisille esiintymisalueilleen. Kompensaatioita voidaan tällöin käyttää estämään tai hyvittämään lajien ihmisille aiheuttamia haittoja.

Tutkin väitöskirjassani kompensaatioiden haasteita ihmisen ja luonnon näkökulmasta, sekä miten kompensaatiot voisivat tukea villiinnyttämistä eli elinympäristöjen ennallistamista sekä lajien leviämistä. Selvisi, että suomalaiset maastossa tehdyt luontoselvitykset eivät ole tarpeeksi kattavia luontoarvojen eivätkä kartoitusten suhteen, jotta niitä voitaisiin käyttää kompensaatiossa. Ekologinen kompensaatio myös siirtää luontoa kauemmas ihmisistä Australiassa, mikä voi aiheuttaa erityisesti kaupunkien ekosysteemipalveluiden vähenemistä. Selvisi myös, että villiinnyttäminen voisi olla edullinen ennallistamiskeino metsitykseen ja luontohyötyjen luomiseen Englannissa. Ehdotin myös uutta talouteen ja osallisuuteen perustuvaa rahoitusmekanismia ehkäisemään susien aiheuttamia vahinkoja ihmisille Suomessa.

Väitöskirjassani tunnistin kompensaatioiden ongelmia ja ehdotin keinoja niiden ratkaisemiseksi parantamalla luontoselvitysten laatua sekä huomioimalla paikalliset yhteisöt ja ekosysteemipalvelut paremmin erityisesti kaupunkialueilla. Ehdotetut keinot kompensaatioiden käyttöön villiinnyttämisessä sisältävät myös potentiaalia luonnon ennallistamiselle sekä ihmisen että muiden lajien paremmalle yhteiselolle.

ASIASANAT: Ekologinen kompensaatio, luontoselvitykset, kompensaatiot, susi, kokonaisheikentymättömyys, luonnonsuojelu, ennallistaminen, villiinnyttäminen

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Abbreviations

BNG	Biodiversity net gain
CBD	Central business district
NNL	No net loss

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Kalliolevo H, Salo M, Hiedanpää J, Jounela P, Saario T, Vuorisalo T. Considerable qualitative variability in local-level biodiversity surveys in Finland: A challenge for biodiversity offsetting. *Journal for Nature Conservation*, 2022; 68: 126194.

II Kalliolevo H, Gordon A, Sharma R, Bull JW, Bekessy SA. Biodiversity offsetting can relocate nature away from people: An empirical case study in Western Australia. *Conservation Science and Practice*, 2021; 3: e512.

III Kalliolevo H, Pérez Chaves P, Hamedani Raja P, Vuorisalo T, Bull JW. Rewilding for biodiversity offsets: A case study of passive ecological restoration on lowland agricultural land for Biodiversity Net Gain in England. Manuscript.

IV Hiedanpää J, Kalliolevo H, Salo M, Pellikka J, Luoma M. Payments for improved ecostructure (PIE): Funding for the coexistence of humans and wolves in Finland. *Environmental Management*, 2016; 58: 518–533.

1 Introduction

The Earth is in environmental crisis. Ongoing climate change, declining biodiversity, and the degradation of ecosystem functions and services are threatening humanity (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES 2019). Human actions that cause habitat loss and degradation are the main reasons for globally decreasing biodiversity and the unprecedented rate of change in nature during the past 50 years (IPBES 2019). An estimated 75 per cent of land area is already significantly altered by human actions and the rate is expected to increase due to existing development pressures (IPBES 2019). Together, habitat loss, wildlife exploitation and introduction of invasive species threaten the existence of about 25 per cent of species in well studied animal and plant groups while monitored species populations have fallen by more than half since 1970 (IPBES 2019; World Wide Fund for Nature 2020). The biodiversity crisis is further exacerbated by climate change that alters the ecosystems and habitats that species are adapted to (IPBES 2019).

While the rapid negative changes in natural environments are continuing, it is becoming clearer how essential nature is to the health and wellbeing of people. Nature provides multiple ecosystem services from clean air and water to global carbon sequestration and local flood prevention as well as raw materials and natural medicines (Millennium Ecosystem Assessment, MEA 2005). The provision of these services requires well-functioning ecosystems which consist of natural and biodiverse habitats creating benefits for both people and nature. As over half of the human population now live in urban areas (United Nations 2018), it is particularly important to secure the local ecosystem services in cities (Niemelä et al. 2010). Importantly, regular contact with nature has been associated with many mental and physical health benefits (Hartig et al. 2014; Sandifer et al. 2015; Marselle et al. 2019). Time spent in nature has been found to reduce stress levels (Tyrväinen et al. 2014), increase the cognitive development of children (Dadvand et al. 2015) and to lower the incidence of allergies (Hanski et al. 2012). In addition, proximity to nature in childhood helps to evolve a stronger connection with nature (Collado et al. 2013; Dopko et al. 2019) which motivates people to become involved in conservation also later in life (Whitburn et al. 2019; Barrera-Hernández et al. 2020).

Despite the multiple benefits nature provides and the intrinsic value of every species on Earth, global aims of halting biodiversity loss such as the Aichi Biodiversity Targets, have recurrently failed to stop the nature decline with current trajectories leading to further failures (IPBES 2019). It is clear that urgent actions are required to minimize any further losses, but also start to reverse existing damages. Such revised targets are included in the Kunming-Montreal Global Biodiversity Framework, completed in late 2022 (United Nations 2022). Moreover, new conservation methodologies and approaches are needed to achieve the biodiversity targets along with more stringent implementation of conventional conservation methods such as protection of species and establishment of conservation areas.

The main approaches studied in this thesis to tackle the biodiversity crisis are different forms of biodiversity related compensations that cover a wide array of actions from species protection to ecosystem restoration and financial payments linked to harmful impacts by large carnivore species. These compensations can be directly targeted to species, ecosystems or ecosystem services to compensate for the damages caused by humans, but they can also be directed to people in order to compensate for the negative impacts that species or ecosystem conservation may cause to them.

Traditional biodiversity related compensations directed to people are monetary compensations for damages usually caused by large species, but compensations can also be paid in advance when harmful impacts are to be avoided by targeting money directly to preventive measures. Loss of nature values (i.e. species, ecosystems) and ecosystem services can be compensated through ecological compensation which aims to enhance damaged nature values by active *in situ* compensation measures. The main focus in this thesis is on using compensations to prevent further nature losses and to reverse existing damages by habitat restoration, but also on considering and including local inhabitants in compensation related decision-making processes to improve conservation outcomes and the overall coexistence of humans and other species.

Ecological compensation or biodiversity offsetting is a widespread method used to compensate for the loss of biodiversity caused by development projects (ten Kate et al. 2004; Bull & Strange 2018). Offsets are the last phase of the mitigation hierarchy, in which the aim is to first avoid, then minimize, restore on site and, as a last option, offset any residual impacts on the environment (McKenney & Kiesecker 2010). The aim of offsetting is to fully compensate for the negative impacts on nature so that the result is No Net Loss (NNL) or a Net Gain of biodiversity (Business and Biodiversity Offsets Program, BBOP 2012). Offsetting is typically done by protecting or restoring biodiversity on a different site from the impact area with ecologically equivalent "like-for-like" biodiversity gains that are meant to be secured in perpetuity (Quétier & Lavorel 2011; BBOP 2012; Bull et al. 2015). The gains must also be additional and must not have happened without offsets (Maron et al. 2015; Moilanen & Kotiaho 2018).

There are currently 37 countries with legal requirements for offsets and over 100 countries have established or are developing NNL policies or ecological compensation (Bull & Strange 2018). Despite the globally popular use of offsets, they have been criticized for multiple issues including inadequate definition of biodiversity (McKenney & Kiesecker 2010; Maron et al. 2012) and challenges to measure biodiversity values and monitor the outcomes of compensation (Quétier & Lavorel 2011; Goncalves et al. 2015; Bezombes et al. 2018; Moilanen & Kotiaho 2018; Josefsson et al. 2021). A study by zu Ermgassen et al. (2019) even found that most offset projects failed to achieve NNL while suggesting also a significant gap between the implementation and evidence of offset effectiveness. In addition to uncertain ecological outcomes, offset policies have overlooked the inclusion of ecosystem services and local people in the offset planning processes (Sonter et al. 2018; Jones et al. 2019; Sonter et al. 2020).

The offset mechanism requires comprehensive nature surveys to estimate biodiversity values on project sites so that the requirements for ecological equivalence and NNL can be met. However, offset metrics do not account for the total biodiversity of a certain site because it would not be possible to measure all biodiversity in practice, in spite of recent eDNA technologies (Beng & Corlett 2020). Instead, surrogates and indicators are used to capture the target nature values recognized in different offset policies (Bull et al. 2015; Bezombes et al. 2018). Target nature values are typically species and habitats protected in national legislation whereas indicators can include e.g. ecosystem structures that are considered important in supporting biodiversity (Maseyk et al. 2016; Bezombes et al. 2017).

In addition to nature values, a high importance is put on the size and location of the project sites. Required size of the offset site can be considerably larger than the associated development area because of the multipliers used to ensure NNL (Moilanen et al. 2009; Laitila et al. 2014). Offsets are also usually advised to be located in the close proximity of the development area to ensure similar nature values between sites, but also to consider local people and ecosystem services (Moilanen & Kotiaho 2018). Because offsetting allows destruction of habitat in one location to be compensated by biodiversity gains at a different location, it can create environmental injustice by spatially relocating nature values and ecosystem services sometimes far from the original sites. As a result, local people on the development areas could lose local ecosystem services while some other communities around offset sites could gain them.

Despite good practice principles for ensuring NNL for people (Bull et al. 2018) and advice to policy makers of including stakeholder perspectives and gaining evidence of local communities being satisfied and compensated for the losses (BBOP

2012; Griffiths et al. 2019; Jones et al. 2019), the impacts on people who lose biodiversity from their local environment are rarely considered (Jacob et al. 2016; Sonter et al. 2018). However, including local people already early on the project lifecycle could increase the acceptability, fairness and effectiveness of compensations (Griffiths et al. 2019).

Biodiversity offsetting typically requires some level of ecosystem restoration and offsets can be used to promote habitat restoration as a way to producing biodiversity gains (Navarro et al. 2017). Restoration can include various goals from restoring species populations and communities to ecosystem structures and functions, but the main aim is to repair ecosystems to a self-sustaining level while assuring the flow of ecosystem services (van Andel & Aronson 2012). Because of large-scale ecosystem degradation, restoring habitats is central in increasing biodiversity but also in mitigating climate change and combating desertification (Aronson & Alexander 2013; Leadley et al. 2014; Navarro et al. 2017). The recently adopted Kunming-Montreal Global Biodiversity Framework (United Nations 2022) also requires that 30% of the world's terrestrial and water ecosystems are being restored by 2030. Restoring habitats such as forests or wetlands, for instance, will not only create biodiversity conservation benefits, but also provide ecosystem services that help in preventing and adapting to climate change such as carbon stores and flood prevention (Ciccarese et al. 2012; Griscom et al. 2017; Bastin et al. 2019).

Habitats can be restored actively by planned management actions or passively by natural succession. Rewilding can be considered as a form of passive restoration when it is based on natural forest regeneration and ecological succession on land abandoned from previously human controlled land uses (Navarro & Pereira 2012). The main aim of rewilding is to restore ecological structures and functions to a level where ecosystems are self-sustaining without continuing human intervention and hence the rewilding effects can sometimes be unexpected (Perino et al. 2019; Carver et al. 2021).

As one third of world's forests have been converted mainly to agricultural land (Ritchie & Roser 2021), rewilding could provide an inexpensive method in restoring woodlands especially on low-producing agricultural areas. This would require motivating landowners to rewild their lands, and preferably existing forests nearby the potential areas to act as seed sources for natural regeneration (Garcia et al. 2010). It is possible to do some restoration activities to assist the revegetation process in rewilding projects, but abandoned farmland has been found to regenerate successfully by itself around the world (Harmer et al. 2001; Chazdon et al. 2020; Broughton et al. 2021).

The term rewilding is also used to describe the recolonization of once lost species to their original habitats (Lorimer et al. 2015). In case of Finland, a long-term political process of wolf conservation that started in the 70's and was strengthened after the accession into the EU has resulted in the return of the gray wolf (*Canis lupus*) in Finland (Aspi et al. 2006). Compensations for local communities, livestock owners especially, are central in areas where human settlements overlap with large predator species territories. Traditionally most economic instruments designed to foster the coexistence of humans and large carnivore species compensate for local people for the occurred damages (e.g. threat to safety, livestock and pets) caused by the predators or promote for tolerance against these species (Skogen 2015).

However, there is little evidence that these kinds of compensations actually work to improve the coexistence by changing human attitudes or behavior in the long term (Schwerdtner 2009; Ravenelle & Nyhus 2017). Even though damage compensations are paid according to the value of direct losses, there can be substantial indirect costs that fall on the local people (Naughton-Treves et al. 2003). For instance in the case of gray wolf predation, the commercial value of lost pets or hunting dogs can be compensated, but compensation does not account for the amount of training spent on the dog or for any emotional ties with the animal (see also Naughton-Treves et al. 2003). Consequently, compensation programs have been advised to shift focus from damage compensations to preventing damages in the first place (Ravenelle & Nyhus 2017). It is also suggested that the inclusion of local people in the decision-making process of compensation schemes could increase the real acceptability and a change of attitudes towards carnivore species (Redpath et al. 2017; Sterling et al. 2017). Hence, compensating all or those who feel and experience that the presence of the wolf reduces wellbeing aligns not only with the mitigation hierarchy as to rather prevent the damages than to pay for the experienced ones, but also with ecological compensation as including and considering local people in the compensation decision-making process.

1.1 Aims of the thesis

The overall aim of this thesis is to study how biodiversity related compensation methods could be used for better conservation outcomes by considering both nature and people. I first study two challenges related to biodiversity offsets (Chapters I–II). The first challenge considers nature and the biodiversity information needed in nature surveys to capture the biodiversity components of interest in a way that ecological equivalence can be reached and area requirements needed for NNL are considered (Chapter I). The second challenge considers people in biodiversity offsetting and studies whether offsetting causes relocation of nature and associated ecosystem services further from people while addressing the potential negative consequences to local communities (Chapter II). The last two chapters examine how compensation policies could support rewilding by facilitating habitat restoration and recolonization of previously lost species (Chapters III–IV). In Chapter III, I study the potential of rewilding agricultural areas back to woodlands in an English policy context that aims not only to prevent further biodiversity loss but to reverse existing damages by creating net gains of biodiversity. Chapter IV on the other hand presents a potential solution to compensate for local people for living in the same areas with gray wolf, which is a large predator species that has recolonized a part of its earlier range in Finland. This chapter also further highlights the importance of considering and including local people in the conservation related decision-making processes as already suggested in Chapter II.

Specific aims by Chapter:

I. To study how well local Finnish biodiversity surveys fulfil the quality requirements of biodiversity assessments needed for biodiversity offsets. Based on this, the aim is also to provide recommendations for the standardization of biodiversity surveys, focusing particularly on the site characteristics and nature values that need to be surveyed for offset purposes.

II. To test if offsets relocate nature further from people in Australia and describe the problems arising from this potential relocation of biodiversity and ecosystem services especially in an urban context, and to address the importance of including local people in the offset systems.

III. To assess whether rewilding lowland agricultural land in England could generate substantial biodiversity gains in the context of Biodiversity Net Gain Policy.

IV. To describe how to involve Finnish citizens and local people living in wolf territories to the compensation decision-making process in order to create a permanent acceptance of living near wolves.

2 Materials and Methods

2.1 Study areas

This thesis consists of case studies from three countries. Chapter I study area is an administrative area of Southwest Finland. Chapter II is a case study from Western Australia (WA), focusing on the state capital city Perth. In Chapter III study area is the whole England. Chapter IV is from Finland and focuses on Finnish wolf territories.

2.2 Data sources

This thesis uses multiple types of data from different origins. Ecological data as biodiversity surveys and deer browsing pressure are used in Chapters I–II. Spatial data as biodiversity offset project locations and land use data are used in Chapters II–III. Questionnaire data that are gathered from workshops, online forum and questionnaire surveys are used in Chapter IV.

2.2.1 Spatial data

Chapter II is based on spatial data derived from publicly available Western Australia Environmental Offsets Register (https://www.offsetsregister.wa.gov.au) which includes all offset agreements in the state. I used data from 158 projects that included spatial locations of both offset and development areas. The spatial data were in the form of a polygon layer presenting the development and associated offset site locations with additional information of the offset type and project developer, for instance. We also obtained the latest Australian population grid data from the Australian Bureau of Statistics (2016) to analyze population densities around project sites.

In Chapter III we used Land Cover Map (Center for Ecology and Hydrology 2017) to categorize agricultural land and forest areas in England, and Terrestrial Ecoregions of the World (Olson et al. 2001) to categorize the original English habitat types, and Deer Distribution Maps created by the British Deer Society (2016) to create deer density maps.

2.2.2 Other types of collected data

Chapter I is based on biodiversity surveys that were collected by the Southwest Finland Centre for Economic Development, Transport and the Environment. The original database included over a thousand biodiversity related documents, but we only chose surveys that were project-based field surveys of multiple levels of organisms in well-defined target areas inside municipalities and conducted since 1997 to include only current legislation requirements. Eventually, we included 206 biodiversity surveys and studied their characteristics mainly based on contemporary Finnish nature conservation legislation and offset criteria gathered from other compensation and nature protection schemes.

We also gathered literature-based data for deer browsing pressure estimates on deer threshold densities related to forest damage and deer densities in broadleaved woodlands in England (Chapter III).

For Chapter IV the data were first collected from an online wolf forum (Salo et al. 2017) where local people living in wolf territories in Finland were able to express their ideas regarding wolf related issues, mainly governance and management, in five different wolf regions. An additional 6th forum was created for people who lived outside wolf territories. One hundred citizens contributed to the analysis and we collected all the different ideas presented in all 582 comments on the forum. Next, we gathered nationwide Internet survey data by using two approximately equal sized samples to gather data related to controversial questions about wolves. The sample frames represented the population of adult citizens (aged 18–79) in 60 municipalities where wolves are regularly present and from 260 municipalities with no regular wolf presence. An independent market research company, Taloustutkimus, administered the surveys and randomly chose the participants from their Internet Panelist's database that included over 40 000 people representing the demographic characteristics of the Finnish population. The response rate for the survey was 30.5%. Rest of the data were gathered in 11 workshops of which 10 were organized in Southern Finland and one in the reindeer herding area in Northern Finland. The purpose of the workshops was to identify concrete ideas for how to modify management actions taken in wolf territories and to use these ideas when compiling the set of activities presented in the national wolf management plan. There were 20–30 participants in each southern Finnish workshop. These people were invited by local Game Management Associations and municipalities because they had the best knowledge of local individuals familiar with wolf issues and were most likely to engage in practical problem solving.

2.3 Spatial analyses

Chapters II–III are based on spatial analysis done on QGIS (QGIS Development Team 2017). I also used ArcMap (ESRI 2015) to calculate biodiversity survey area sizes in Chapter I. In Chapter II, I studied whether biodiversity offset projects create relocation of nature by first calculating the distances between development sites and their associated offset sites. As the spatial data was a polygon layer depicting the offset and development sites, we created centroids for all of the polygons, and used a distance matrix to calculate the distance between associated offset and development sites. We used mean distance when there was more than one offset and/or development location in a single project. To study whether the offset sites tend to be further from the centre of Perth than their associated development sites, we fixed a centroid for the Perth central business district (CBD) polygon, and calculated the distance of offset and development areas to this CBD centroid. For our final analysis, we categorized projects into those with development sites 0–50 km from the CBD (n=52) to evaluate relocation inside the urban area of Perth. Lastly, we studied differences in the human population densities around development and offset sites by first creating a centroid of Perth with a 200 km buffer to include also the next two biggest cities in Western Australia and then adding a 1.5 km buffer around all development and offset sites inside the 200 km buffer. After this, we used the Point Sampling Tool to extract the population density information from the raster data around all the sites of the 114 projects. We calculated the average population densities separately for development sites and offset sites and compared these values within a project.

The spatial analysis of Chapter III is based on the rewilding potential of English lowland agricultural areas. In this study, rewilding potential means how likely restoration is to succeed but also the ecological condition that a certain site can achieve through passive restoration. The potential was calculated by evaluating site suitability for passive restoration, based on forest cover, arable land cover and deer browsing pressure. We first created a raster map of deer browsing pressure by digitizing deer distribution information (British Deer Society 2016) to absence or presence and then adding the literature estimates of deer densities in broadleaved woodlands for each deer species in 10×10 km grid which was the map size provided for deer distribution. We also created separate layers for both arable land and forest cover raster by categorizing them in three classes (1–3) based on the cover percentages in each pixel. The classes were decided by dividing the highest overall cover percentage (38% forest, 95% arable land) in a pixel by three. After categorizing the habitats and deer browsing pressure in three categories, we used QGIS 3.22 to calculate the combined scores of these three variables for each pixel. Then we categorized the resulting scores of 3–9 again in the following 3 categories: 3–4 poor, 5–7 moderate and 8–9 good rewilding potential which equal to the Biodiversity

Metric 3.1 that requires habitat condition scores from 1 (poor) to 3 (good). The condition is based on habitat's key physical features and ability to support typical species. Next, we calculated the arable land area covered by different potentialities. We considered areas with good rewilding potential to most likely result in good condition habitat after passive restoration whereas areas with moderate to poor rewilding potential would be passively restored into poor and moderate condition.

2.4 Transdisciplinary action research

We used transdisciplinary action research in Chapter IV because we engaged various methods on various wolf territories. Action research is a methodology of research generally applied in the social sciences seeking transformative change while taking action and doing research (for action research, see Westlander 2006 and for transdisciplinary research, Leavy 2011).

First, we developed the wolf forum discussion in three phases. The first phase consisted of three questions considering problematic wolf behavior and solutions to improve the situation. Phase 2 extended the discussions about how to improve the situation by specifying potential modifications to wolf-related actions and decisions. The discussions were developed around three more questions based on a preliminary classification of the proposed modifications offered in response to phase 1: (i) How can we decrease negative wolf–human encounters? (ii) How can we create a separation from the wolf, improve tolerance, and create benefits from the presence of wolves? and (iii) How can we improve interactions and collaboration around wolf-related issues? In Phase 3 we encouraged detailed discussions of a territory-level institutional system – a working group – for managing human–wolf interactions. We suggested the working group arrangement and asked participants to discuss how such a group would function – who would organize the group, who would be included, and what tasks would be pursued?

Second, to measure the willingness of respondents to provide private donations in support of Finnish wolf management we provided them with 3 hypothetical scenarios (i.e., donation targets). We first told respondents that wolf reproduction and wolf-related damages to human property happen in wolf territories, and then asked whether they would be willing to participate as monthly donors to a fund exclusively used to support one or more of the following management activities in those territories: (1) 'To cover the labor costs related to the construction of an LC-fence that prevents wolf attacks on livestock'; (2) 'To acquire dog-protecting vests for organizers of field trial tests who then lend them to hunting dogs participating in the trials'; and (3) 'To finance any activity in the territory to support humans' coexistence with the wolf, the criteria of which is that wolves within the territory have reproduced successfully over the two previous springs, and there is no hard evidence that animals from the territory have been killed by poachers.’

Third, we organized all southern Finnish workshops by the same model: (i) an individual exercise in which participants identified and wrote down key solutions to the problem; (ii) small group deliberation on these alternatives; and (iii) a large group discussion to identify and come to an agreement on territory-level management actions and potential projects that could be pursued. We began with the individual ideas because we wanted to prevent what is known as ‘‘group think’’ that polarizes deliberation (Solomon 2006; Sunstein 2003). The method was modified in the Northern Finland workshop because there are no permanent wolf pack territories in the region.

2.5 Statistical methods

In Chapter I, we used cluster analysis to study whether the biodiversity surveys are sufficiently similar to each other to allow a comparison between them based on the surveyed nature values. In clustering, surveys that are similar to each other and dissimilar to the surveys belonging to other clusters are grouped together. We used X-means clustering model (Pelleg & Moore 2000) which does not require determination of the cluster numbers a priori but instead uses Bayesian information criterion to make local decisions about which subset of the current cluster centroids should split themselves in order to better fit the data. The statistical analyses were performed using the RapidMiner software (version Studio Large 9.6.000., https://rapidminer.com /, Mierswa et al. 2006). I also used paired t-test to study the difference between reported and measured area size of biodiversity survey locations.

In Chapter II, I used Wilcoxon signed-rank test to study if there was statistical difference between the distance of offset and development areas from the centre of Perth. Paired t-test was used to study the difference of human population densities between offset and development sites. Natural log transformation with an added constant was applied to human population calculations to allow the transformation of zero values.

In Chapter III, we performed a sensitivity analysis to study the uncertainty in resultant forest vs arable land cover achieved by changing the percentages needed for different suitability scores. We increased and decreased each of the percentage categories individually by 5% for forest and 10% for arable land cover because of their different maximum coverages (38% forest, 95% arable land). We cross tested all different scenarios which created 8 different results.

In Chapter IV, we made Fisher’s exact test to examine if there is a statistically significant association between the willingness to participate as donors to the wolf territory activities and the place of residence or background (animal owner, hunter, parent of a young child). When describing the two-by-two correlative associations between the willingness to support or not two different targets, we calculated pairwise χ^2 measure π with scale that varies from -1 to +1, and associated bias-corrected bootstrapped confidence intervals (BCI) taking 1000 resamples with replacement of the observed dataset. The calculations were made with SYSTAT 13-software.

3 Results and Discussion

3.1 Biodiversity surveys need improvement

In Chapter I, we analysed 206 nature surveys from Southwest Finland based on Finnish nature legislation and biodiversity offsets requirements. We found three major qualitative problems with biodiversity surveys in Finland with regards to offset requirements and achieving NNL of biodiversity. Firstly, the surveys do not assess nature values comprehensively enough. This is because they do not always include all the mandatory legislation-based nature values nor the so-called "non-mandatory good practices encouraged by the offset policies" such as rare and nearly-threatened species (as defined by Bezombes et al. 2018). When the legislation criteria are not met, endangered and protected species and habitats could be lost or damaged without adequate compensation. Also, if the aim is to offset only legally protected species and habitats, many other nature values could be lost in the process.

The second shortcoming in the surveys is inadequate spatial data. There were considerable difficulties in identifying the locations of some surveyed sites in the data despite the fact that the size and location of the project areas are crucial for offset outcomes (zu Ermgassen et al. 2019). Some of the surveys had no map at all and most did not report the project area size. Furthermore, some reported areas differed considerably from those indicated in associated maps of survey areas, although there was no significant difference overall ($t = 0.61$, $df = 19$, $p = 0.548$). Additionally, mapping needs to account for the whole landscape context around the project sites mainly to ensure habitat connectivity and identify potential pressures to offset sites (Quétier & Lavorel 2011; Berges et al. 2020), but also to consider ecosystem services and distances between project sites (Moilanen & Kotiaho 2018).

The last main problem with the surveys is the considerable difference between the assessed nature values that was revealed by the cluster analysis, which divided surveys in three different groups. This is problematic because in order to reach ecological equivalence, nature values must be comparable and hence surveys should assess the same nature values by similar methods on different project sites (Quétier & Lavorel 2011; Maseyk et al. 2016). A potential explanation for this variability is that there have been no official standards and requirements for biodiversity surveys in Finland. The surveyor might investigate only nature values specified by the client, but the interests and expertise of the surveyor could also affect which values are surveyed.

Based on our results, we recommend that the data collection for nature surveys would be standardized to include valuable species and habitat types listed in national legislation as well as those nature values under the risk of unfavorable conservation status. In any case, habitat types of a site should be identified in nature surveys. Best available geoinformatics systems need to be used to consider habitat networks and the whole landscape while limiting offsets within similar biogeographical areas. These surveys should be conducted by certified nature surveyors to ensure adequate ecological skills particularly in species and habitat identification for comparable and comprehensive surveys. These basic standards for future biodiversity surveys consider the principal aspects of offsets and the initial ecological and geographical data needed to reach NNL. Nevertheless, calculating equivalent losses and gains requires even more comprehensive surveys of the areas to estimate the ecological quality or functioning of the sites. Furthermore, different habitat types require habitat-specific inventories whereas our data focused mainly on general nature values that can be applied to different habitats.

In addition to adequate biodiversity data, achieving NNL in practice is also dependent on other successful methods and design decisions on ecological issues, and furthermore also on governance and social and economic considerations (e.g. McKenney & Kiesecker 2010; Damiens et al. 2021; Rhodes et al. 2023). The implementation challenges include decisions about the allowed time lag between damage and offsets, and how restoration uncertainties are accounted for (Moilanen & Kotiaho 2018). Damiens et al. (2021) have also discussed the challenges of establishing lasting and additional biodiversity gains that are crucial in achieving NNL (see also Gardner et al. 2013; Maron et al. 2015; Moilanen & Kotiaho 2018). The monitoring and evaluation of offset activities and outcomes throughout the project cycle is essential and should be organized by official authorities that can ensure the transparency, appropriateness and adherence to the mitigation hierarchy. However, developers should cover the long-term management and monitoring costs, which has been found to be challenging in practice (Damiens et al. 2021). Nevertheless, careful definition of NNL and indicators to capture target biodiversity are in the core of successful offset design that is able to achieve real conservation outcomes.

The next steps in the planning process for offset surveys requires specific decisions on the indicators used to measure the target biodiversity, whether this is concentrating on species or on ecosystem condition. Comprehensive and high-quality biodiversity surveys are required for documenting and monitoring the actualization of anticipated gains or to demonstrate where the offsets fall short. Without adequate and compatible surveys the nature values of different sites cannot be compared and achieving NNL will be highly unlikely.

3.2 Offsetting relocates nature further from people

In Chapter II, we found empirical evidence that offsets relocate nature away from people by moving green areas further from the city center and to areas of lower population density. The result is clear in the Perth city area defined as within 50 km from the city center (number of projects = 52) with offsets being significantly further from the center than the associated developments (Z=4.85, p<0.001, r=0.67) (Figure 1). The mean values were also clearly different as developments (mean=31.4 km) were on average 22.9 km closer the city center than offsets (mean=54.3 km). Moreover, although in 42% of the studied projects (n=158) the distance between associated development and offset sites was less than 5 km, Figure 2 shows that offsets (n=114) were still established in significantly less populated areas (t=4.34, df=113, p<0.001, d=0.34). The mean population density around development sites was 315.7 person/km^2 while for offset sites it was 185.2 person/km^2.

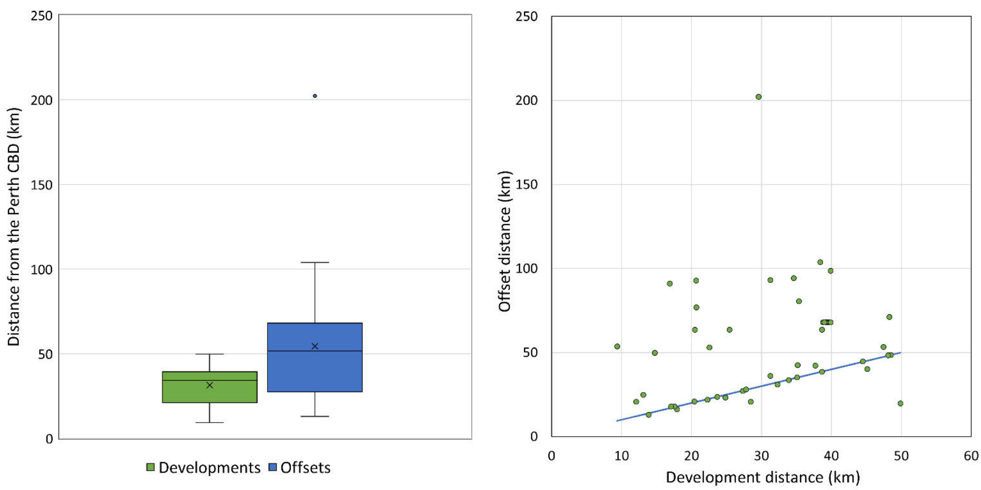


Figure 1. Offset and development site distances (km) from the Perth CBD for projects that have development site within 50 km from the CBD. The solid line on right shows where the dots would fall if developments and their associated offsets were the same distance from the CBD.

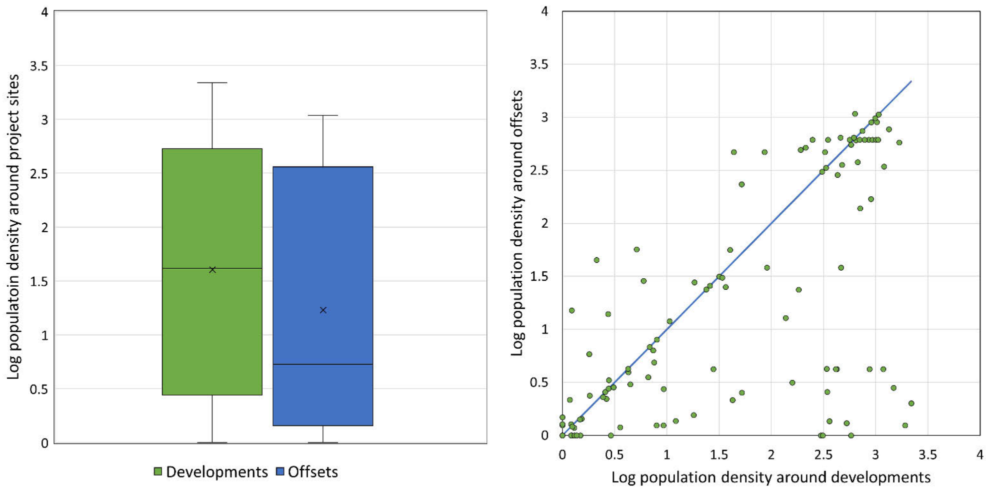


Figure 2. The natural log with an added constant transformed human population density around offset and development sites (right) with the solid line showing what would be expected if the densities around offsets and developments were the same. Box plots of the population densities around development and offset sites (left).

Because comprehensive offset data registers are lacking in many countries, our case study has provided important information of the relocation caused by offsetting. Before this, only BenDor et al. (2007) have found a similar relocation trend in US wetland mitigation scheme. The relocation is probably due to the lack of potential offset areas near development sites when it comes to size and needed biodiversity values, but the urban land prices can also be very expensive. However, offsetting nature further from populated areas has multiple consequences for people. Firstly, it decreases the overall amount of nature values in cities with already lower levels of green space while increasing the separation between people and nature. Secondly, it changes the ecosystem services available to local people which not only creates environmental injustice, but also decreases the availability of ecosystem services that contribute to human health and overall city functionality in the first place (see e.g. Niemelä et al. 2010; Bateman & Zonneveld 2019). However, the relationship between biodiversity and ecosystem services can be variable, and particularly cultural ecosystem services can be established already at low levels of biodiversity (Harrison et al. 2014). Urban nature is also important for biodiversity itself and cities have been found to be biodiversity hotspots hosting a variety of species (Seto et al. 2012; Ives et al. 2016).

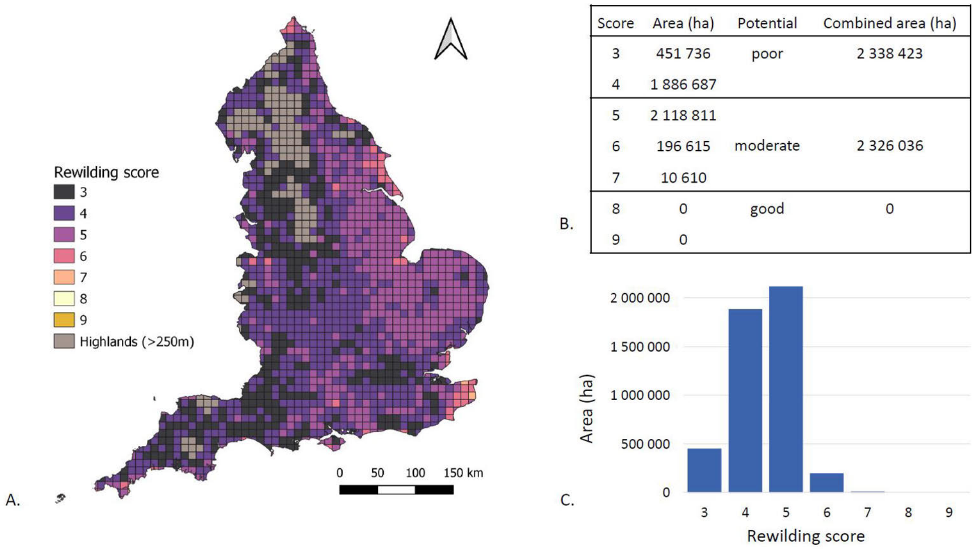
Based on these results, we recommend offset policies to require spatial proximity of development and their associated offset sites to ensure the people losing nearby nature and ecosystem services would be the ones to be compensated by offsets.

However, as biodiversity is the priority in offset schemes and finding ecologically equivalent sites can be difficult (Sonter et al. 2020; Rhodes et al. 2023); additional criteria might be required to ensure that people who lose closeness to nature are compensated through the delivery of other nature experiences. This could be additional to the ecological offset, which might be needed to be at a different site so that the NNL target would not be compromised. Because of these various ecological and social reasons, the negative impacts on nature should be avoided in the first place as already required in the mitigation hierarchy. On-site management of biodiversity values at the development sites should also be enhanced. Nevertheless, we emphasize the importance of ensuring that offsets do not reduce the proximity to natural areas to the general public especially in urban areas.

3.3 Rewilding as a way to create biodiversity gains

In Chapter III, we created an analysis of the rewilding potential in lowland agricultural areas of England, based on country's BNG policy, existing ecological knowledge on passive restoration and the possible outcomes of rewilding.

We found that rewilding potential is concentrated to southeast England with eastern part of England having more potential than the western part of the country (Figure 3). The sensitivity analysis also showed that the most potential rewilding areas are the same in all scenarios with the original result being the average option. When we converted the rewilding potential to condition based on Biodiversity Metric 3.1, it resulted in an almost equal amount of sites that could be restored to poor and moderate condition. Only one scenario in the sensitivity analysis had sites that could achieve good condition. Based on our results, we used Biodiversity Metric 3.1 to calculate the generated biodiversity units for different woodland habitat type options with poor and moderate target condition and other variables such as time to target condition and locality. The amount of generated units varied from 3 650 856 to 32 562 736 units and 0.78–7.34 units/ha whereas the estimated need currently per year is around 38 000 biodiversity units (calculated on Biodiversity Metric 3.1 with numbers based on currently available land use change data in England from Ministry of Housing, Communities and Local Government 2020). This means rewilding a cumulative 0.15–1.06% of agricultural land back to woodlands would compensate for the annual development impacts. The amount of produced units is significant especially in the habitat types that create the majority of units.



Score	Area (ha)	Potential	Combined area (ha)
3	451 736	poor	2 338 423
4	1 886 687		
5	2 118 811		
6	196 615	moderate	2 326 036
7	10 610		
8	0	good	0
9	0		

Figure 3. Map of England with rewilding potential as scores from 3 (poor potential) to 9 (good potential) across the country (**A.**). Table with areas (ha) of different rewilding potential scores (**B.**). Figure of rewilding scores and associated areas (ha) (**C.**). Highlands are marked separately in the map as our analysis is based on lowland agricultural land.

Using rewilding as an option for BNG policy would require some adjustments to the current practice of generating and calculating the units. As the effects of rewilding can be unexpected and the BNG calculator requires that the target habitat type is specified in advance, there might be a need for some restoration activities to guide the regeneration to the desired habitat type or creating the biodiversity units after restoration when the habitat type can already be identified. In fact, it is advised that at least some biodiversity gains are created before any habitat is lost (Maron et al. 2012), but most BNG projects are currently changing certain losses to uncertain future gains that are expected to actualize years after the losses (zu Ermgassen et al. 2021).

Despite the shortcomings of our analysis such as unknown soil type, climate conditions and uncertain deer browsing effects, natural regeneration has occurred on abandoned farmland and resulted in closed-canopy forests in different parts of England within 20–50 years with trees and shrubs colonizing the areas even in a decade (Walker et al. 2000; Harmer et al. 2001; Broughton et al. 2021). Because of our large-scale analysis, it is likely there are also agricultural sites with good re-wilding potential that even further decreases the costs of rewilding and increases the amount of generated units. Moreover, sites could achieve good condition especially if some initial management activities (e.g. fencing to prevent intensive grazing or planting small forest patches) would take place in order to aid the regeneration.

According to the additionality principle of offsets, land that is abandoned for rewilding only to produce biodiversity gains for offset purposes can be accounted as offsetting. If the landowner would have rewilded the land anyway for other reasons, the gains are not truly additional and offset principles are violated. Nevertheless, rewilding could be used as an inexpensive method to generate biodiversity gains while also advancing England's objective of forestation.

3.4 Better coexistence between wolves and people

The nationwide wolf online forum provided a comprehensive amount of information of wolf related issues, but the main focus of discussions evolved around a mechanism that would support local decision making of wolf management. One forum participant suggested a cooperation group that would consist of local people and be established in each wolf territory or territorial area (consisting of a few neighboring territories). This idea was further supported in the wolf survey and workshops.

In the workshops, individual participants first identified 375 measures to improve the coexistence. Eventually, this resulted in 59 measures to be implemented in the new wolf management plan. The cooperation groups were also discussed in all Southern Finnish workshops and they were agreed to implement the identified measures. Hence, according to our compensation scheme, they would also make decisions on how to use any funds raised for wolf management.

Because the government and its administration have not indicated any extra financial resources to support wolf management, there is a need for new privately funded economic scheme to address the damages, concerns, and preventive measures identified in the workshops. The nationwide wolf survey revealed there is a public willingness to fund wolf management as 26% of the respondents were willing to donate at least to one of the three scenarios to improve the coexistence of wolves and people living in wolf territories. The highest willingness (19% of respondents, representing 22% of adult Finnish population) was to donate money without any specific preference for management activities except a set population target for wolves. The individuals' place of residence did not affect the willingness to donate, but there were some small differences between the functional groups (see Results of Chapter IV for further details).

Based on our results, we proposed a new economic instrument that we called Payments for Improved Ecostructure (PIE). The cooperation groups would be the most important new organization in the wolf related ecostructure where spatial and institutional structures driving human and wolf actions meet and cause impacts. These groups would be established by Regional Wildlife Councils while the organization of the groups would be administered by national "Wolf Territory Stewards" coordinating payments and information exchange among different territory level stakeholder groups. The cooperation groups would engage in discussions with stakeholders and citizens regarding their territory issues so that the collective will of the community could be formulated to improve the coexistence. The multiple tasks administered by cooperation groups are explained in detail in the Discussion of Chapter IV. Funding for the PIE tasks would be based on crowdfunding (on crowdfunding, see Belleflamme et al. 2014) through an online portal administered by the Wolf Territory Stewards. Citizens could target their money amongst multiple different managerial activities based on the needs that cooperation groups have deemed important. This way, donors could also directly support the specific activities they consider to be the most important. The individual donors would also be granted with wolf-related rewards. See details in the Discussion of Chapter IV.

To conclude, PIE would apply mitigation hierarchy in a sense that the idea is to fund preventive management actions that aim to avoid and minimize harmful impacts in the first place (such as protecting animals with electric fences or dogs with vests), and only after that compensate for the possible occurred damages that could not have been avoided. This damage compensation is already normally done by the government, but preventive measures are lacking funding although they should be prioritized (Ravenelle & Nyhus 2017). PIE would also engage local people in the decision-making while enabling the participation of the general public to contribute for wolf management based on their own values. This mechanism would not only enhance the viability of the wolf population by preventing and compensating for economic losses but would also create financial grounds to enhance approval of wolves in the territories as locals would be supported with those measures they have deemed important in living next to wolves. This also highlights the importance of gathering adequate data and monitoring the effects to improve compensations. The ultimate aims are to change the ecostructure of wolf territories and enable the evolution of peoples' habits toward a permanent acceptance of wolves.

To this date (2023), 36 cooperation groups have been established and they discuss the territory issues with stakeholders and citizens as suggested in PIE (Finnish Wildlife Agency 2023). There is also a national level person who coordinates the cooperation groups. In addition, the establishment and activity of groups are incentivized with monetary contributions to local game management associations. However, the compensation system based on cooperation groups and citizens' monetary contributions is yet to be established.

4 Conclusions

In this thesis, I have investigated biodiversity related compensations; the practical problems of compensations and how to overcome them, and also potential new mechanisms of using compensations to restore ecosystems and to support human coexistence with wildlife.

In Chapter I, I found that biodiversity surveys that provide the basic information of nature values on potential project sites need to be improved in order to achieve adequate and comparable measures to calculate for NNL of biodiversity. I have provided the first steps of improving the execution of these surveys. In Chapter II, I found that offsets tend to relocate nature further from people, which creates multiple problems for citizens from reducing ecosystem services to environmental injustice and separation between nature and people. I have suggested considering local people in offset projects by requiring spatial proximity of project sites or compensating for lost ecosystem services as separate measures to local people. In Chapter III, I found rewilding lowland agricultural areas in England could be used as a productive way in generating biodiversity gains, but this would require creating at least some gains before any habitat clearance takes place or accepting gains in unspecified habitat types. In Chapter IV, I suggested a new economic instrument to support human-wolf coexistence that is based on local decision-making and collective private funding to promote for a lasting change of attitudes towards wolf presence acceptance.

Overall, the findings of my thesis suggest that compensations can have challenges with adequate data when it comes to nature and people. I have presented general ecological and geographical data requirements that should be obtained on the field when evaluating biodiversity for compensations. Furthermore, I studied the potential of restoring forests passively for offset purposes although obtaining more place-specific data would be beneficial when designing smaller scale restoration and there could be challenges with data if the target habitat type would have to be decided in advance. In addition to ecological data challenges, I found that local people have not been adequately considered in the studied biodiversity related compensations. This means that besides ecological and geographical data, obtaining data on ecosystem services that are important to local people should be included in offset surveys.

As mapping and assessing the full array of ecosystem services at a certain site can be difficult, compensation projects should include local people in the planning process from the beginning so that the views of local people regarding their nearby nature would be considered. This applies also to rewilding as those sites could be situated to provide benefits for large communities, particularly in and close to urban areas with little green space. Including local people in the compensation projects since the beginning is important also in more traditional economic compensations such as the studied case of gray wolf. The mitigation hierarchy should be applied in compensations targeted to people that may encounter damages caused by certain species as preventing damages is more likely to change the attitudes of local people than compensating for occurred losses only. This again emphasizes the role of local communities in compensation projects. Altogether, my thesis highlights the importance of including local people in the compensation process and obtaining data of the needs of these people while also monitoring the effects.

Despite the criticism and identified problems with compensations, an increasing amount of countries are applying them and will continue using them as a part of their policies. Therefore, it is essential to improve the practices of both ecological and traditionally used economic compensations. My thesis has provided information on how to improve both methods, but it should also be noted that not everything can be compensated for and damages should be prevented in the first place. It is crucial to follow the mitigation hierarchy and always to avoid any clearance of nature, especially of those habitats still in their natural state. Furthermore, when ecological compensation is used, it should aim for a net gain or a net positive impact on biodiversity in order to provide conservation outcomes that focus on reversing nature damages.

Additionally, as my thesis has shown, there are problems related to both biodiversity and people in compensation schemes. Although biodiversity is at the center of conservation biology, conservation is inevitably intertwined with human societies. Therefore, it is essential to study biodiversity compensation methods from both perspectives as to provide the best solutions for nature while gaining the acceptance of people and changing human attitudes more positive towards nature conservation in the long term. Overall, it is important to ensure that biodiversity related compensations are established in a way that include and consider local people and their rights to biodiverse environments with lasting and comprehensive biodiversity gains from species to ecosystems.

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Hanna Kalliolevo

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