Assessing the effectiveness of different approaches to species conservation

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“Conservation is a state of harmony between men and land.”

Aldo Leopold – *A Sand County Almanac*, 1949

Contents

The thesis is based on the following articles, which are referred to in the text by their Roman numerals:

I **Santangeli, A.,** Lehtoranta, H. & Laaksonen, T. (2012) Successful voluntary conservation of raptor nests under intensive forestry pressure in a boreal landscape. *Animal Conservation*. 15(6): 571-578.

II **Santangeli, A.**, Arroyo, B. & Bretagnolle, V. Identifying effective actions to guide volunteer-based national conservation efforts for a ground-nesting farmland bird. Manuscript.

III **Santangeli, A.** & Arroyo, B. Assessing the cost-effectiveness of alternative conservation measures for a ground-nesting raptor in managed agro-ecosystems. Manuscript.

IV **Santangeli, A.,** Högmander, J. & Laaksonen, T. Returning white-tailed eagles breed as successfully in landscapes under intensive forestry regimes as in protected areas. *Animal Conservation* (in press).

V **Santangeli, A.,** Wistbacka, R., Hanski, I. K. & Laaksonen, T. (2013) Ineffective enforced legislation for nature conservation: A case study with Siberian flying squirrel and forestry in a boreal landscape. *Biological Conservation*. 157: 237-244.

Table of contributions

	I	II	III	IV	V
Original idea	TL, HL	VB	BA, AS	TL	RW, TL
Study design	TL, AS	VB, BA, AS	AS, BA	TL, AS	AS, TL, IH
Analyses	AS, TL	AS	AS, BA	AS, TL	AS
Empirical data	HL	VB	BA	JH	RW, AS
Manuscript preparation	AS, TL, HL	AS, BA, VB	AS, BA	AS, TL, JH	AS, TL, IH, RW

AS = Andrea Santangeli, HL = Hannu Lehtoranta, TL = Toni Laaksonen, BA = Beatriz Arroyo, VB = Vincent Bretagnolle, JH = Jouko Högmander, RW = Ralf Wistbacka, IH = Ilpo Hanski.

Abstract

Humans are the main cause of the on-going large-scale biodiversity crisis, mostly through processes like habitat loss and fragmentation, and habitat degradation. The recent recognition of the scale and rate of biodiversity erosion has stimulated strong political and institutional reactions, culminating in the implementation of a large number of conservation initiatives. Such efforts have been largely insufficient to revert or slow down the rapid loss of biodiversity. Commonly, conservation resources have been allocated based on decisions supported by traditional knowledge or expert opinion rather than scientific evidence. Therefore, it is relevant that interventions are evaluated, to ultimately allow learning from past actions and taking better decisions in the future.

With this thesis I aim to provide evidence needed to improve the effectiveness of different approaches to conservation of some species affected by anthropogenic activities. In doing so, I considered conservation interventions implemented mostly on private land with different underlying approaches: Voluntary and inexpensive (based on self-motivation of landowners); Voluntary market-based (landowners are compensated); Compulsory land reservation or legislation (landowners have no choice).

I first evaluate the effectiveness of a conservation program aimed at protecting raptor nests in private forests of North Karelia in eastern Finland. I show that here an inexpensive voluntary approach, based on self-motivation of landowners, may represent an effective instrument for achieving conservation with very limited financial resources. This approach was effective not only at eliciting participation of local forest owners, but it also provided ecological benefits to the raptor species considered.

Relevant outcomes for practical conservation can also emerge when multiple interventions are compared. This was the case for nest protection of the Montagu's harrier breeding in cropland of Spain and France. In France, protection of nests from harvesting operations has been achieved on a voluntary basis. Here I show that the most effective interventions to enhance nest productivity were those that not only protect from harvesting, but also from predation. This was achieved by erecting a protective fence around the nest. On the other hand, some nest protection measures in Spain were more expensive due to payments to farmers. Here, temporary removal of the chicks during harvest operations or relocation of the nest to a nearby safe place, as well as harvest delay, were the most effective measures to enhance nest productivity. Harvest delay was also the most expensive among all measures, therefore removal or relocation of the nest should be prioritized wherever it is operationally feasible. Interestingly, the most commonly employed measure, the retention of a small buffer of un-harvested crop, was also less effective compared to the other means.

Unexpected but positive outcomes for conservation management emerged also from an evaluation of the effects of nest site protection for breeding White-tailed eagles in south-western Finland. The species was breeding as often and successfully in protected and unprotected areas, which suggests that compulsory and expensive protection through land reservation may not be necessary under the studied conditions. The species apparently thrives also in unprotected land subject to some levels of anthropogenic activities. I found opposite results in a study on protection of flying squirrel sites in Finland. Here I provide evidence indicating that the enforced legislation to protect the species habitat in Finnish forests is ineffective. The species occupancy at sites protected according to the law strongly declined following tree harvest. This indicates that the primary objective of the legislation (i.e. prevent deterioration of the sites where the species occurs) are not met. This is due to the fact that conservation of flying squirrel's habitat may conflict with forestry interests, and thus restrictions have been largely set in favour of the latter and at the detriment of the former.

The case studies presented here indicate that evaluating the effectiveness of past actions is important. This step allows understanding whether past efforts have reached their initial objectives. Only with the strength of this evidence it is possible to adaptively revise current conservation plans and increase the chances of reaching the desired outcome from any given action. This is particularly relevant in the modern era, where conservation challenges are enormous, and the resources limited. Therefore, it is crucial that any implemented effort produces the best possible outcome for conservation.

Tiivistelmä

Ihmistoiminta on tärkein syy meneillään olevaan laaja-alaiseen biodiversiteettikriisiin, lähinnä habitaatin vähenemisen, fragmentaation ja laadun heikkenemisen kautta. Biodiversiteetin vähenemisen mittakaava on synnyttänyt voimakkaita poliittisia ja institutionaalisia reaktioita, jotka ovat johtaneet useisiin erilaisiin suojelualoitteisiin. Nämä toimenpiteet ovat olleet riittämättömiä pysäyttämään biodiversiteetin katoamista. Suojeluun varattujen resurssien käytöstä on usein jouduttu päättämään ilman tieteellistä tutkimustietoa. On tärkeää, että suojelutoimenpiteiden vaikutuksia arvioidaan, jotta niitä voidaan kehittää ja jotta suojelun käytössä olevia rajallisia resursseja voidaan allokoida oikein.

Väitöskirjani tavoite on arvioida erilaisten suojelukeinojen tehokkuutta joidenkin ihmisvaikutuksen piirissä olevien lajien kohdalla. Tutkin erityisesti seuraavien yksityismailla toteutettujen suojelukeinojen tehokkuutta: vapaaehtoinen ja halpa (maanomistajan motivaatioon perustuva), vapaaehtoinen markkinahintaiseen korvaukseen perustuva ja pakollinen lakisääteinen suojelu.

Tutkin ensin Pohjois-Karjalassa toteutetun yksityismailla sijaitsevien petolintujen pesien suojeluun tähdänneen projektin tehokkuutta. Maanomistajien pesäpaikkojen vapaaehtoiseen suojeluun perustuva osoittautui hyväksi keinoksi suojella pesäpaikkoja hakkuilta vähillä kustannuksilla. Lähestymistapa osoittautui hyväksi myös petolintujen kannalta, sillä ne jatkoivat pesintäänsä hakkuun jälkeen.

Käytännön suojelutyön kannalta tärkeitä tuloksia voidaan löytää vertaamalla eri suojelumenetelmien tehokkuutta. Vertasin Ranskan ja Espanjan viljelymailla sijaitsevien niittysuohaukkojen pesäpaikkojen suojeluun käytettyjen menetelmien onnistumista. Ranskassa pesäpaikkoja suojellaan vapaaehtoisesti. Osoitan, että pesien tuottavuuden kannalta paras tulos saavutetaan kun pesä suojataan paitsi sadonkorjuulta myös pedoilta pystyttämällä pesän ympärille verkkoaita. Espanjassa pesäpaikkojen suojelu on kalliimpaa silloin kun viljelijöille maksetaan korvauksia. Pesimätuloksen kannalta parhaat suojelukeinot olivat poikasten väliaikainen tai pysyvä siirtäminen sadonkorjuun tieltä tai sadonkorjuun myöhentäminen. Sadonkorjuun myöhentäminen oli menetelmistä kallein, joten poikasten siirtäminen oli kustannustehokkain vaihtoehto. Tähän asti yleisimmin käytetty menetelmä, pesän ympärille jätetty pieni suojavyöhyke, osoittautui heikoimmin toimivaksi vaihtoehdoksi.

Suojelun kannalta yllättäviä mutta positiivisia tuloksia sain tutkiessani merikotkien pesäpaikkojen suojelun vaikutuksia lajin pesintään Lounais-Suomen rannikkoalueella. Pesissä pesittiin yhtä usein ja yhtä onnistuneesti sekä suojelluilla että suojelemattomilla alueilla. Pesäpaikkojen ympäristön laajamittainen suojelu ei nykyisissä olosuhteissa vaikuta siten tarpeelliselta vaan laji menestyy myös ihmistoiminnan vaikutuksessa olevilla alueilla. Päinvastaisia tuloksia sain tutkiessani liito-oravia, joiden lakisääteisen suojelun keinot eivät vaikuta odotetulla tavalla. Lajin esiintyminen paikalla hakkuun jälkeen aleni merkittävästi kun paikalle jätettiin vain ohjeiden mukainen suojapuusto. Tämä ei vastaa lakia, jonka mukaan liito-oravan esiintyminen ei saa vaarantua. Liito-oravien suojelun ja metsätalouskäytön välinen ristiriita on siten nykykäytännön mukaan ratkaistu jälkimmäisen hyväksi.

Nämä tutkimukset ovat esimerkkejä siitä, että käytettyjen suojelukeinojen tehokkuutta on syytä arvioida. Vain tällaisen todistusaineiston kautta on mahdollista sopeuttaa käytettyjä suojelukeinoja ja lisätä todennäköisyyttä saavuttaa haluttu päämäärä. Tämä on oleellista, sillä suojelun haasteet ovat valtavia mutta siihen käytettävissä olevat resurssit vähäisiä. On siksi erittäin tärkeää, että tehty panostus tuottaa suojelun kannalta parhaan mahdollisen lopputuloksen.

SUMMARY

1. INTRODUCTION

1.1. Anthropogenic impacts on ecosystems and wildlife

Humans have used natural resources for thousands of years, and created and maintained extensive traditional landscapes that nowadays support important biodiversity (Pain and Pienkowski 1997; Tucker and Evans 1997; Wright et al. 2012). However, during the last century, and particularly since the 1960s, the global expansion of human population, coupled with changes in consumption, has posed progressively increased pressure to the limited resources that ecosystems provide (Fischer et al. 2007; Foley et al. 2005; Imhoff et al. 2004; Millennium Ecosystem Assessment 2005; Vitousek et al. 1997). As a consequence, natural and traditional ecosystems have been widely replaced or modified by human activities with the ultimate goal of increasing production in order to satisfy an ever growing demand for resources (Foley et al. 2005; Millennium Ecosystem Assessment 2005; Vitousek et al. 1997). Globally, about 60% of the ecosystems are considered degraded or used in an unsustainable way (Millennium Ecosystem Assessment 2005).

The intensification of resource extraction in recent decades has in many ways transformed the landscape in which wildlife thrive (Millennium Ecosystem Assessment 2005). Overall, anthropogenic changes such as habitat loss, degradation and fragmentation are recognised as perhaps the most important drivers of extinctions of populations and species in terrestrial realms (Fahrig 1997, 2003; Millennium Ecosystem Assessment 2005; Pimm et al. 2006). Habitat loss entails extreme changes in habitats that become unable to support the original ecosystem processes, functions and species pool (Groom et al. 2006). Habitat loss is often coupled with another distinct process, habitat fragmentation, which is the breaking apart of once continuous habitats (Fahrig 2003; Rybicki and Hanski *in press*). These processes have received a large share of conservation attention, a clear example of which is represented by the documented loss and fragmentation of tropical rainforests and the resulting impacts on wildlife (Bradshaw et al. 2009a; Gibson et al. 2011).

Parallel to loss and fragmentation, the process of habitat degradation entails more subtle impacts that may affect many but not all of the species in a community and may be temporary (Groom et al. 2006). Habitat degradation affects virtually all ecosystems where humans have access to (e.g. through agriculture, extraction activities, pollution and biotic changes), and can be particularly severe in the developed world. Here, habitat degradation induced by intensification in farming, but also in forestry practices, has massively accelerated during the last half century (Bradshaw et al. 2009b; Robinson and Sutherland 2002; Stoate et al. 2001; Tscharntke et al. 2005; Östlund et al. 1997).

Across large tracts of open land of the developed world, farming practices have intensified through increasing use of pesticide, herbicide and fertilizer inputs, whereas widespread mechanization has favoured the simplification/homogenization of agro-ecosystems (Green et al. 2005; Millennium Ecosystem Assessment 2005). The change has been so rapid that most of the threatened taxa occur in farmland landscapes (Millennium Ecosystem Assessment 2005; Robinson and Sutherland 2002; Tscharntke et al. 2005). The mechanisms by which species are affected by intensive farming are multiple, from depletion of food resources and breeding sites, to direct mortality caused by mechanization of farming operations (Robinson and Sutherland 2002; Stoate et al. 2001; Tscharntke et al. 2005). Additionally, intensification has often induced changes in associated wildlife communities and trophic interactions. Specialist species are often replaced by generalist species able to thrive in simplified landscapes (Millennium Ecosystem Assessment 2005; Pain and Pienkowski 1997; Stoate et al. 2001; Tscharntke et al. 2005).

Forests are used by humans in multiple ways worldwide, and as such they have experienced the most rapid alteration rate among all biomes (Dirzo and Raven 2003). The human impact on boreal forests, which comprise about one third of the wooded cover globally, spans a very long history during which this landscape has been slowly but progressively modified (Hansson 1992). However, as observed for farmland landscapes, the most rapid and profound alterations have taken place starting from the 1960s when industry-oriented forestry practices were widely introduced (Bradshaw et al. 2009b). In the case of Northern Europe, intensification of forestry practices has mostly been achieved through the widespread increase in clear-cutting and forest regeneration practices (Kuuluvainen 2009). This recent shift has created forest landscapes largely dominated by even-aged tree stands while the extent of old-growth forests was progressively reduced. These rapid changes are posing a serious threat to the associated species and communities inhabiting old-growth forests (Kuuluvainen 2009; Rassi et al. 2010; Schmiegelow and Mönkkönen 2002; Östlund et al. 1997). Despite their rapid alteration rate and spatial extent, the conservation of biodiversity in boreal biomes is perhaps still much overlooked (Bradshaw et al. 2009b; Hanski and Hammond 1995; Warkentin and Bradshaw 2012).

1.2. Approaches to species conservation

Species and populations have often been the focus of conservation actions because they represent the essential unit of evolution. Although there are limits in the species-approach to conservation (Likens and Lindenmayer 2012), many of the international treaties focus at the species or higher taxa level (such as the Habitats Directive of the EU, CITES, Convention on Migratory birds) and lists of threatened species are often compiled at the country, continent and global level (e.g. numerous national red lists, Endangered Species Act ESA, IUCN Red List). The threats affecting single species are often easily detectable and therefore targeted actions can be implemented through several means, from habitat protection (by instituting protected areas or implementing legislation), habitat restoration, environmental education, to intensive management through predator eradication, extra feeding, breeding habitat provision (using e.g. nest-boxes), reintroductions, re-stocking and *ex-situ* conservation, among others (Groom et al. 2006). Many of these actions (e.g. habitat protection) have been based, especially in the past, on compulsory top-down approaches (Miller et al. 2011). However, after the realisation of the importance of the social dimension in determining conservation success (Knight et al. 2010; Knight et al. 2011; Smith et al. 2009), a "social conservationist" movement has grown within the community of conservation scientists (Miller et al. 2011). The social conservation movement advocates sustainable development within a socially just framework, and in this context, voluntary participatory approaches to conservation may represent an optimal way forward. This approach has often succeeded in areas of the developed world where most of the land is privately owned (Frank and Müller 2003; Langpap and Wu 2004; Mönkkönen et al. 2009; Reed 2008; Whittingham 2007). However, most voluntary participatory approaches so far implemented involved some monetary compensation to the land owners (hereafter called market-based; such as the agri-environment schemes in the EU), while far rarer are voluntary means which only rely on the self-motivation of single individuals to achieve conservation (hereafter called inexpensive).

So far, a wide range of different intervention measures have been implemented in order to ameliorate the status of many threatened species worldwide (Cullen et al. 2001; Heller and Zavaleta 2009). These efforts have often entailed considerable, but yet insufficient, financial investments (McCarthy et al. *in press*). Although successes have been reported in several cases, they are still largely insufficient to halt the erosion of biodiversity worldwide (Butchart et al. 2010; Hoffmann et al. 2010), and this may be only partly attributed to the limited funds available for conservation. In fact, in some cases well intentioned conservation actions supported by adequate funding have even resulted in contradictory outcomes (Ausden et al. 2001; Blanco et al. 2011; Walsh et al. 2012). These cases highlight the fact that conservation funds are not always spent in the most effective way (Ferraro and Pattanayak 2006).

1.3. Divide between conservation science, policy and practice

Despite the primary aim of any conservation scientist is to produce research which is relevant to solve real-world conservation problems, still a great share of published studies have little impact on applied conservation (Knight et al. 2008; Laurance et al. 2012b; Milner-Gulland et al. 2010). This was largely attributed to the lack of communication between most conservation scientists working in academia and practitioners (Knight et al. 2008; Laurance et al. 2012b; Milner-Gulland et al. 2010). As a result, scientists often address questions that are not relevant to practical conservation, and therefore more communication between the two groups is needed. On the other hand, practitioners often neglect published scientific material, even if relevant, because it is inaccessible or because they lack time or background to critically appraise its content (Pullin et al. 2004). In an attempt to solve this gap, recent effort has been placed onto identifying relevant issues that should be addressed by conservation scientists (Braunisch et al. 2012; Sutherland et al. 2011a). At the same time, the launch of new platforms, such as Conservation Evidence (www.conservation evidence.com) and Collaboration for Environmental Evidence (www.environmentalevidence.org) aim to provide easily accessible information on the effectiveness of interventions. They will ultimately support practitioners in their decision making.

A perhaps even larger divide also exists between conservation scientists and policy makers. Traditionally, scientists have proceeded independently and rather separately from policy, and this has constrained the applicability of scientific findings to conservation policy (Brosnan and Groom 2006). Therefore, a better integration between these two fields is also required (Sutherland et al. 2012). However, conservation policy is a broad and complex discipline, and policy makers usually seek to accommodate contrasting interests from different groups (Brosnan and Groom 2006). In this complexity, it is crucial that conservation scientists provide clear and robust evidence in order to minimise the probability of adverse consequences resulting from poor policy decisions. Attempts to fill this gap have been recently made (Sutherland et al. 2012; Sutherland et al. 2011a; Sutherland and Freckleton 2012).

1.4. Importance of evaluating effectiveness

Particularly in the past, conservation initiatives have not always been based on solid and updated scientific evidence (Pullin and Knight 2009; Sutherland et al. 2004). Rather, decisions were often made in the dark or based on anecdotes, personal experience and traditional beliefs of questionable origin and effectiveness (Cook et al. 2010). This situation arose because scientific evidence was largely inaccessible or non-existing at the time when conservation decisions had to be made with urgency. This lack is perhaps the main factor undermining the success of many conservation actions (Pullin et al. 2004). Knowing the effectiveness of a given intervention is fundamental in order to take appropriate evidence-based conservation decisions and increase their impact (Sutherland et al. 2004). Results of evaluations can be directly used to revise conservation plans in order to make better decisions within an adaptive management framework (Salafsky et al. 2002). Additionally, providing the evidence of the effectiveness of interventions is also important to justify current spending and convince donors to maintain and increase their investments in conservation.

Unfortunately, despite their immense importance, evaluations are rarely undertaken in conservation (Ferraro and Pattanayak 2006; Jones 2012; Pullin et al. 2004). As a consequence, the field of conservation biology lags far behind other disciplines, like medical science, which develops through the practice of systematic review of the evidence (Friedland et al. 1998; Sutherland et al. 2004). However, a similar revolution as that occurring in medical sciences has been launched in conservation (Pullin and Knight 2001; Sutherland et al. 2004) and it is slowly taking place (see e.g. Dicks et al. 2011; Williams et al. 2012).

As recent studies demonstrate, the availability of data is perhaps no longer the most important constraint to engaging in evaluation studies (Howe and Milner-Gulland 2012a). Rather, it is the lack of skilled analysts, as well as lack of funding and the underestimation of its importance within academia, that probably still limit the number of evaluation studies (Arlettaz et al. 2010; Possingham 2012). This is not admissible given the current biodiversity crisis, the scarcity of conservation resources and availability of monitoring data. Therefore, there is an urgent need to engage scientists in addressing this relevant topic in conservation (Gimenez et al. *in press;* Howe and Milner-Gulland 2012b).

2. AIMS OF THE THESIS

The general aim of this thesis is to contribute to filling the existing gaps between conservation science, practice and policy by providing evidence needed to improve the effectiveness of conservation decisions. In doing so, questions of high relevance for conservation practice and policy targeting single species are identified and addressed by means of robust scientific methods. All of the questions relate to quantifying the effectiveness of past and currently implemented interventions for species conservation in human-altered landscapes. The conservation measures under study have been implemented by means of very different approaches, from bottom-up voluntary participation (with or without compensation) to top-down compulsory means (through legislation or land reservation). They thus entail very different costs and also target different species living in contrasting environments, from boreal forests of Northern Europe to farmland landscapes of Mediterranean countries. More specifically, the thesis breaks down to three questions relevant to applied conservation.

1. The first question asks whether a voluntary participation (with no compensation) approach to conserve raptor nests on private forests of Finland can achieve a positive response from forest owners, and whether the subsequent conservation intervention can be effective in maintaining nest occupancy (**chapter I**).

2. The next question aims to assess the effectiveness of alternative voluntary interventions (with different costs) for protecting nests of a ground nesting raptor in farmland and to provide recommendations for cost-effective management of the species (**chapter II** and **III**).

3. The last question aims to assess the effectiveness of two compulsory measures (land reservation and legislation) at preventing detrimental effects of anthropogenic activities on two different species in the Finnish environment (**chapter IV** and **V**).

3. MATERIALS AND METHODS

3.1. Study landscapes

The studies comprising this thesis took place in contrasting environments, from forest to farmland. All these are managed ecosystems where anthropogenic resource extraction activities are thought to affect the persistence of the species considered, and as such they have been the focus conservation initiatives.

Three of the five studies took place in separate boreal forest areas of Finland (**chapter I**, **IV** and **V**). About 67% of the country is covered by forests, 45% of which are privately owned (Finnish Forest Research Institute 2011). The vast majority of forested landscape in Finland is nowadays profoundly altered by modern intensive forestry practices aimed at timber production. Intensive forest management commonly involves a rotational tree-growing cycle that usually lasts 60 to 100 years. Throughout one full cycle, an initial forest regeneration phase is commonly followed by two or three light thinning stages before a final clear-cutting, when all trees are harvested. Thus, clear-cutting often targets the oldest forest patches present in the landscape. These patches progressively decrease in area, while younger even-aged and mono-specific commercial tree stands become dominant. In 2010, clear-cutting affected about 145000 hectares of forest across Finland (comprising about 0.5% of the whole forestry land; Finnish Forest Research Institute 2011). Within this heavily modified landscape, species dependent on old-growth forests at some stages of their life-cycle are likely to suffer (Rassi et al. 2010).

The remaining two of the five studies (**chapter II** and **III**) included in this thesis took place in agro-ecosystems of France and Spain, respectively. In these countries, as in most of the remaining areas within the European Union (EU), farming practices have rapidly intensified over recent decades (Pain and Pienkowski 1997). The rapid changes have progressively rendered this habitat inhospitable to many taxa which have expanded and adapted to traditionally maintained farmland mosaics during a history of millennia (Pain and Pienkowski 1997; Robinson and Sutherland 2002; Stoate et al. 2001). As a consequence, this habitat now supports the largest share of species of conservation concern in the EU (Pain and Pienkowski 1997; Robinson and Sutherland 2002; Tucker and Heath 1994).

3.2. Study species and conservation measures

In the boreal environment, middle- and large-size raptors breeding in forest, like the common buzzard, Northern goshawk and European honey buzzard (*Buteo buteo*, *Accipiter gentilis* and *Pernis apivorus*, respectively) require for nesting large trees which are usually found in patches of old growth forest. These three species were studied in the Region of North Karelia, where they have been the focus of a conservation program (**chapter I**). The three raptors commonly reuse the same large stick nest for several years. Because these nests often locate in forests old enough to be clear-cut, they were frequently and accidentally destroyed during clear-felling operations. From 2000 onwards, a conservation program was launched to preserve raptors' nests from forest clear-cutting in private land of North Karelia. Landowners were approached and proposed to voluntarily set aside a small forest buffer around the nest on their land. Participation was exclusively based on self-motivation, with no incentive involved.

Another large sized raptor that has been thought to require old and undisturbed forests for nesting is the white-tailed eagle (*Haliaeetus albicilla*). This species has also been thought to be potentially affected by increasing human encroachment during recent decades within its breeding range in Finland, which mostly concentrates in archipelago and coastal areas. Thus, conservation efforts to protect the land around its breeding sites were made (**chapter IV**). This was initially achieved through the designation of a large and fragmented protected area (the Archipelago Sea National Park) from the 1980s. The Park nowadays covers an area of about 500 km^2 and includes over 2000 islands and islets. Although its designation was not exclusively aimed at protecting known white-tailed eagle nests, these were often included within the boundaries of the National Park at the time when it was first designed and subsequently expanded. As the eagle population increased in recent years and more nests were found on private and state owned forests outside of the National Park, these were often protected by means of designing small protected areas (usually of up to few hectares in size). These protection measures are imposed to the private owners by means of fixed term contracts. Forestry operations are not allowed within any of these protected areas. The costs of protection are particularly high for nests on private land, and the money are yearly sought from the Ministry of Environment through the national budget for nature conservation.

Modern intensive forestry was also indicated as the main cause of decline of several other species that are considered old-growth forest specialists (Rassi et al. 2010). Among these, the flying squirrel (*Pteromys volans*) occurs across large areas of Southern Finland and is often found in the commercially most valuable forests (Santangeli et al. 2013). These are usually old spruce (*Picea*)- dominated stands with additional deciduous trees which provide food and breeding sites (i.e. natural tree cavities; Mönkkönen et al. 1997). Within the EU, the majority of flying squirrel population occurs in Finland, and the species is thus listed as Annex IV in the Habitats Directive. This implies that its habitat should not be deteriorated, and in Finland this has generated strong debate because of the conflict between habitat protection for flying squirrel and forestry interests. Under this complex situation, guidelines for habitat protection have been issued following an update in the national Finnish legislation (Anonymous 2004). It is therefore important that the effectiveness of issued guidelines is evaluated (**chapter V**).

In farmland landscapes of western Europe, intensification has been mainly achieved by implementing large scale mechanization of harvesting operations (through combine harvesters). This was found to be particularly detrimental for ground nesting birds as it may cause brood and adult mortality when harvesting takes place during the breeding season (Grüebler et al. 2012; Kragten et al. 2008; Newton 2004). One such species affected by mechanical harvesting is the Montagu´s harrier (*Circus pygargus*; Arroyo et al. 2002). In western Europe, this raptor nowadays breeds mostly in cereal crops (Arroyo et al. 2003) where approximately 60% of the nestlings are unfledged at harvest time. Therefore, they may be at very high risk of mortality from harvesting operations in absence of any nest protection measure. In France and Spain, but also in other countries, several protection measures for the species have been implemented during recent years or decades. In Spain (**chapter III**), the most common conservation interventions adopted to protect Montagu´s harrier nests were: 1) Temporary removal of nestlings during harvesting or relocation of nestlings a few days before harvest to a safe place nearby (e.g. field edge or un-harvested plot); 2) Retention of a small buffer of un-harvested crop around the nest; 3) Harvest delay, where a farmer is compensated for postponing the harvest time of the whole field or a large portion of it. These three interventions are hereafter called "removal/relocation", "buffer" and "harvest delay", respectively. In France (**chapter II**), the most commonly adopted interventions to protect nests in cultivated land (e.g. on cereal and fodder) were: 1) Buffer (with or without a protective fence); 2) Relocation of the nestlings (with or without a fence placed after relocation) to a safe place nearby; 3) Removal for captive breeding and subsequent release; 4) Signaling the nest location to the farmer with a flag put near the nest. These interventions are hereafter called "buffer/fenced buffer", "relocation/fenced relocation", "removal", and "flag", respectively.

3.3. Species data

In all of the five studies, the target species were surveyed by experienced volunteers by means of searching for breeding sites and visiting them often enough to accurately assess occupancy (**chapter I** to **V**), and additionally breeding success (whether an occupied nest has produced at least one fully fledged young, **chapter IV**) or productivity (the number of fully grown offspring produced; **chapter II** and **III**).

3.4. Study design and analyses

For **chapter I** and **V** we collected and sorted the data in order to fit a before-after-control-impact (BACI; Stewartoaten et al. 1986) design. In doing so, we split the sites into two treatment groups, one including sites that were affected by a clear-cut, and one used as control (where there has been no clear-cutting nearby). We then split the history of each site in the first group into two periods, before vs. after the clear-cutting, and we did the same for the control sites, but in this case the periods were split artificially (because no clear-cut occurred nearby). The interaction term between the group type (clear-cutting vs. control) and the period (before vs. after) was tested. This interaction was of primary interest, as it allowed verifying if changes in site occupancy from the period before to the period after were due to the occurrence of a clear-cut or not.

In **chapter II**, **III** and **IV** we identified nests under different conservation measures and compared the relative effectiveness (in terms of occupancy, breeding success or productivity) among the different protection measures and/or with that of unprotected nests (see the methods in each individual chapter for more details).

The presence of multiple observations within the same site (which may violate the assumption of independence) was duly accounted for in the models wherever required.

4. RESULTS AND DISCUSSION

4.1. Effectiveness of voluntary inexpensive measures

Voluntary inexpensive approaches for nature conservation have been largely overlooked, even in recent years when the importance of the social dimension has been increasingly appreciated (Knight et al. 2010; Knight et al. 2011; Smith et al. 2009) and resources for conservation are scarce. In fact, market-based voluntary entry means have been largely prioritized over inexpensive approaches exclusively based on self-motivation of the individuals (de Snoo et al. *in press*). However, the former have been found to provide mixed outcomes and usually are short term solutions, whereas the latter may induce a more long lasting response to conservation and may be more sustainable in the long term (de Snoo et al. *in press;* Kleijn et al. 2006; Lokhorst et al. 2011; Mönkkönen et al. 2009).

In the region of North Karelia (eastern Finland), we found that most of the forest owners approached and asked (not told) to participate in conserving nest sites of forest raptors on their land have positively joined the program (97% of the 327 owners approached during 2002-2006; **chapter I**). Upon acceptance, the forest owners were involved in discussion to modify the forest cutting plans in order to retain the nest. The unprecedented success of this program in obtaining participation from forest owners can be explained by a number of conditions that have been fulfilled in North Karelia at the same time. Firstly, the program identified and targeted individual landowners who were made fully responsible for the fate of the raptor nest. This approach has been recently advocated for conservation in farmland landscapes, where nature conservation should be mainly placed in the hands and will of farmers (de Snoo et al. *in press*). Secondly, during discussion about the forest cutting plans, the owners were let totally free to decide how large a forest area to retain around the nest. Transferring the power of authority to each landowner allows preserving their personal autonomy, which is known to be a powerful source of motivation beyond economic incentives (DeCaro and Stokes 2008; Lokhorst et al. 2011; Pretty and Smith 2004). Thirdly, the forest owners in North Karelia were approached by a person (Hannu Lehtoranta) who is close to their own interests because he works for an institution (the regional forestry center) which has a long history of advisory support about forestry planning in Finland. Being approached by a somewhat "peer" has likely enhanced an initial positive perception by the forest owners, which could trust the approaching person as well as the program much more as if they were approached by a member of an external or unknown institution. Lastly, the fact that raptors are charismatic species that the general public would like to be preserved may have contributed to the positive response observed. In fact, about 50% of approached forest owners were willing to visit the nest site, sometimes carrying along their entire family, which clearly indicates they have an interest in these species (**chapter I**).

In farmland landscapes of the EU most of the land is also privately owned and conservation faces similar challenges as those applying in forested landscapes. In France, conservation of Montagu's harrier nests has been implemented for years through a variety of interventions, all of which are inexpensive, as no compensation was paid to the farmers. This conservation program was run across most of the breeding range of the species in France, and as such, it had to cope with a diversity of farmers' attitudes towards conservation (**chapter II**).

Therefore, in order to be able to succeed in this heterogeneous social landscape, conservation practitioners have employed a more dynamic and flexible approach (consisting of several alternative protection measures) compared, for example, to that implemented in North Karelia (see **chapter I**) where the attitude of forest owners to conservation was generally positive across the Region. In France, relying on a set of different interventions offers great advantages. Practitioners have here the choice to apply the most appropriate measure for each local situation (in terms of farmers attitude), and increase the chances of putting a nest under protection irrespective of the farmer's perception. For example, if a farmer was found hostile to conservation, less invasive/intrusive interventions could be implemented to protect the nest. Therefore, although participation to the conservation program was not quantified in France, and in some cases was not even directly sought for by approaching farmers, the multitude and variety of available intervention options has increased the chances of a nest being protected by any of the available measures.

However, simply obtaining the participation of landowners to conservation programs is not enough to determine ultimate success. It is also necessary to quantify the effectiveness of implemented interventions from a biodiversity perspective. In this light, we show that the loss of nests of the three raptor species in the Region of North Karelia (**chapter I**) has massively decreased after the project was practically started in 2000 (Figure 1). Further, we show that the retained nests (**chapter I**) with a small surrounding buffer (hereafter "low-buffered nests") were used by the three raptor species with a similar frequency as nests used as controls ("high-buffered nests"; Figure 2).

These results indicate that the retention buffers around raptors' nests, as they are currently implemented (e.g. with an area of 0.24 ha on average), are able to maintain nest occupancy after the clear-cut occurred and therefore they can be considered as an effective mean. However, when analyzing data from the post-clear-cut period at low-buffered nests, we found evidence that nest occupancy increased with the distance to the clear-cut (Figure 3) and with the size of the retained buffer (**chapter I**). This information is relevant for practical conservation. It suggests that, when setting the size of the forest buffer around a nest, retaining

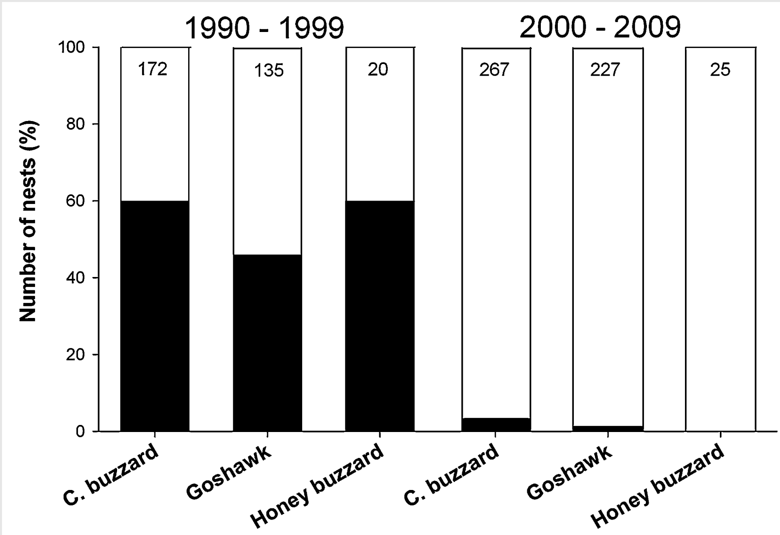

Figure 1. Percentage of nests of each of the three forest raptors destroyed by forestry (black part of each bar) in North Karelia during the 1990s (three leftmost bars) compared to the situation in 2000s (three rightmost bars) after the start of the nest conservation program. Total number of nests per species is shown within each bar.

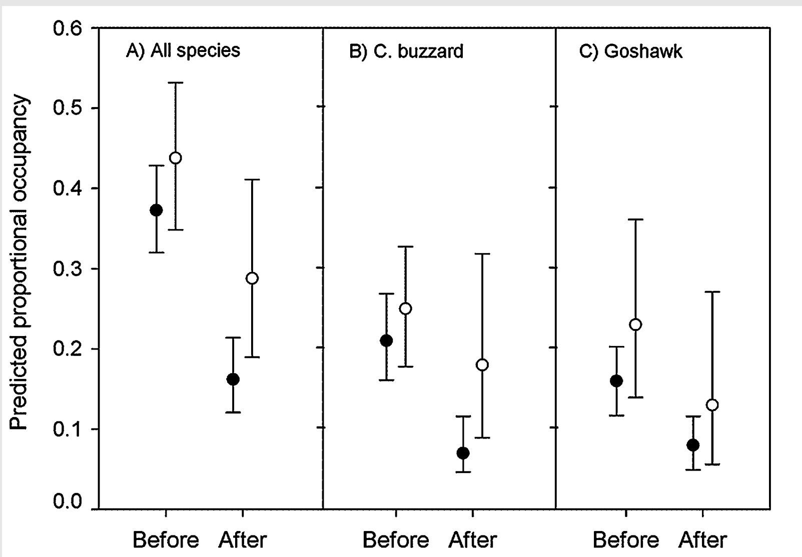

Figure 2. Proportional nest occupancy (mean ± 95% CIs) in the periods before and after the clear-cut for high-buffered (filled symbols; used as controls) and low-buffered (empty symbols; retained as part of the conservation program) nests. Within the high-buffered nests, data were artificially split into before vs. after in similar proportion as for the low-buffered nests (see methods). Panel A) shows results from the model where all three species are combined, B) for the common buzzard, and C) for the goshawk separately. (Reproduced from Santangeli et al. 2012. Animal conservation 15:571-578).

very small areas (down to a single tree) should be avoided (**chapter I**) because this lowers the occupancy of nests below natural levels. Overall, these results can serve to convince forest owners that retaining a forest buffer can provide a large benefit to breeding raptors.

In cultivated areas of France, a variety of measures have been implemented during recent years in order to increase the chances of protecting Montagu's harrier nests from harvesting destruction, and in some instances, also from nest predation. In our study (**chapter II**) we could show that, among all adopted interventions, two were the most effective at raising nest productivity to a level that will most likely allow for long-term population persistence (Arroyo et al. 2002). The two most effective measures were the fenced buffer and fenced relocation, and both allowed for simultaneous protection of nestlings from harvesting destruction and from predation

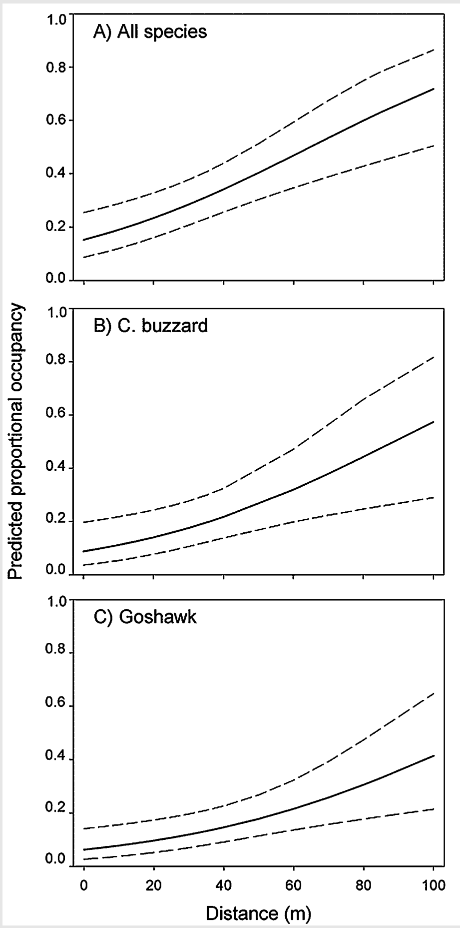

Figure 3. Predicted nest occupancy (mean ± 95% CIs) as a function of distance to the clear-cut area within a range of 100 m to the low-buffered nests considering A) all species combined, B) common buzzard (c. buzzard), and C) goshawk. Effect of distance was statistically significant for all species combined, the common buzzard and the goshawk ($p < 0.001$, $p = 0.005$ and $p = 0.003$, respectively). (Reproduced from Santangeli et al. 2012. Animal conservation 15:571-578).

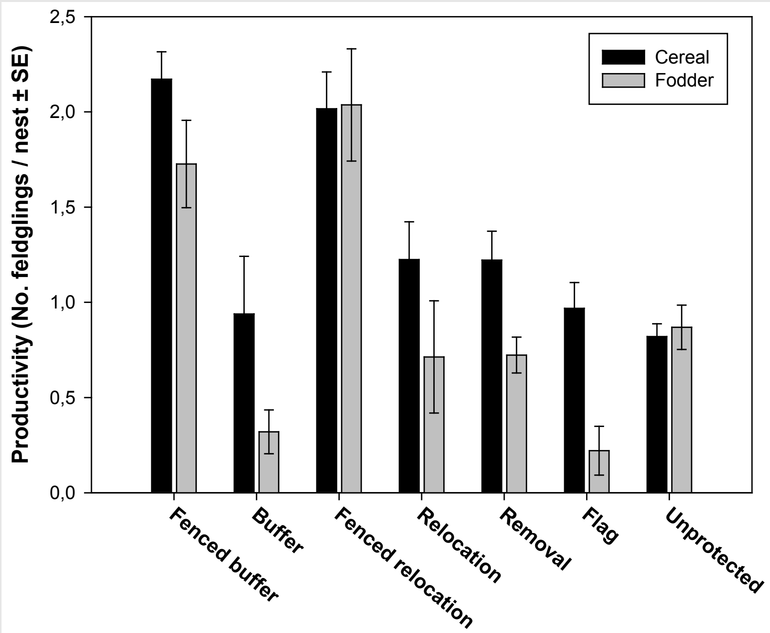

Figure 4. Productivity at nests of the Montagu's harrier located in farmland under six intervention measures, as well as unprotected nests, within cereal (black bars) and fodder (grey bars) during 2007 – 2011 in France. Values depict least square means (±SE) derived from GLMM (see methods in **chapter II**). For results of the multiple comparisons between protection types, see Appendix S2 in **chapter II**.

through a protective fence (Figure 4). Measures that did not involve a protective fence were significantly less effective. In terms of practical management for the species at the national level, the results suggest that, in order to effectively protect nests in cultivated landscapes, one of the two highly effective protection measures (fenced buffer or fenced relocation) should be used in each case.

The fact that both these interventions are similarly effective is good news for practical implementation of nest protection in a heterogeneous social-landscape. Here, farmers' attitude towards conservation may differ in each case. For example, in areas where farmers do not allow the retention of a buffer, despite this being very small in size, the fenced relocation may be used instead. However, the applicability of the fenced relocation may be constrained by the availability of a safe site within a short distance to the nest. This condition may be rather common in intensively cultivated areas where the field size is large, and possibly also the distance to the nearest field edge (Robinson and Sutherland 2002). In this latter case the fenced buffer may represent a valid alternative.

Increased mechanization of farming practices in recent decades, coupled with increased predation impacts in altered landscapes, have resulted in considerable brood losses in farmland bird species, particularly those nesting on the ground (Arroyo et al. 2002; Grüebler et al. 2012; MacDonald and

Bolton 2008; Pain and Pienkowski 1997). Consequently, conservation interventions have been implemented to reduce such losses (Koks and Visser 2002; Schekkerman et al. 2009; Smith et al. 2011). However, the effectiveness of alternative conservation measures aimed to simultaneously protect from predation and harvesting have been rarely evaluated within the same study. In this context, our findings provide interesting insights for applied management. They clearly show that protecting from predation, in addition to harvesting, is very important for a ground-nesting bird like the Montagu's harrier. The relative effect of predation is likely mediated by the nest exposure during the post-harvest period, and we show that the sole protection of a nest from harvesting is not enough to prevent a decrease in productivity and most likely population declines. Nest predation is widely considered as the main cause of nestling mortality (Martin 1995) and in the Montagu's harrier it was previously found to be associated with nest concealment (Gillis et al. 2012). Therefore, nest predation should be given more attention when making conservation decisions for protecting ground-nesting species. This is particularly relevant within human-altered landscapes where increased predation may strongly reduce the impact of conservation efforts (but see also Grüebler et al. 2012).

4.2. Effectiveness of voluntary market-based measures

In Spain, conservation of Montagu's harrier nests in cropland has been implemented through a voluntary participatory approach (**chapter III**). However, contrary to France, here some of the adopted measures, such as harvest delay, may entail large losses of yield to a farmer. Therefore, compensation was provided in order to delay harvest, and in some cases also for retaining a small buffer (often without a fence) of un-harvested crop around the nest.

The results show that nest protection measures such as harvest delay, removal/relocation and buffer yield significantly higher productivity than unprotected nests, and values for the former two were also marginally higher than productivity at nests protected with a buffer (Figure 5).

As expected, productivity also increased as the difference between harvest and laying date grew bigger ($ß = 0.024 \pm 0.005$; mean and SE). This pattern was the same irrespective of the nest being protected by any measure or being unprotected. Larger values of this difference mean that nestlings have more time for leaving the nest before harvest. This latter result indicates that the overall negative impact of harvest operations is most severe when crop harvest occurs early in the season and/or when breeding is late. Overall, the average productivity at protected nests with any of the three measures more frequently approached the critical threshold of two fledglings per nest, which was found, from a simulation study, to be a safe level in terms of extinction risk of the local population (Arroyo et al. 2002). This suggests that the species here, as already observed in France (**chapter II**) is in strong need of intensive management in order to minimize the risk of population extinction. In Spain however, regional administrations face a variety of conservation challenges (regarding several species and habitats) while resources are progressively being cut. Therefore, identifying the most cost-effective measures for conservation in such critical situation is the key to obtain the best outcome out of limited resources. In this light, our results suggest that removal or relocation and harvest delay

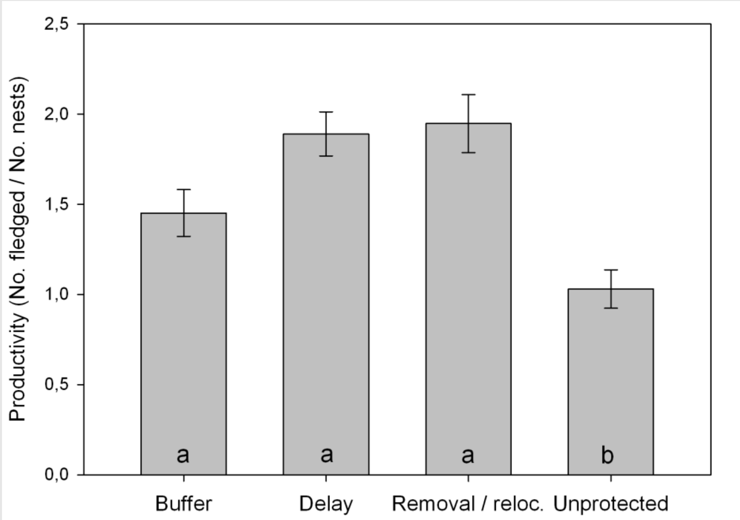

Figure 5. Productivity (mean ± SE) of Montagu´s harrier nests under different conservation measures as well as unprotected nests in Spain. Letters within the bars indicate results from multiple comparisons: bars sharing the same letter are not significantly (α = 0,05 after correction for multiple testing) different from each other.

will likely minimize the extinction risk under a larger tract of the gradient depicting the difference between laying and harvest date and should thus be preferred over the buffer. Unfortunately, as it is currently implemented in Spain, the buffer, despite being the most widely adopted measure, yields a somewhat lower productivity than the other two interventions. As such, the buffer may not represent an effective option.

In terms of practical conservation management, the findings suggest that chicks' removal or relocation and harvest delay, given their high effectiveness, should be prioritized when conservation decisions are to be made and the budget allows for their implementation. The fact that both measures are similarly effective is of great advantage to local practitioners. It allows them to choose either according to the agronomic characteristics of the area, the budget available and the acceptance of each intervention by local farmers. Temporary removal could be implemented, for example, in situations when the straw is not packed immediately after harvest. This allows leaving the nestlings concealed in the straw after harvest. On the other hand, relocation may be operationally feasible where the nest is located close to a field edge or un-harvested field. This is most common if field size is small and crop diversity is large. However, agricultural intensification trends in Spain lead to reduction in stubble fields, removal of the straw from the ground, increase in field size and dominance of monocultures in many areas. These factors may constrain the application of removal and relocation interventions. In these conditions, delaying harvest may represent an equally effective alternative. However, this measure entails more potential constraints relating to farmers acceptance to delay harvesting, and larger costs associated to the compensation to the farmers. Because of its high costs, harvest delay may become economically unsustainable under current budget reductions as a consequence of the present economic crisis.

Based on the evidence emerging from France (see **chapter II**), predation can have a strong negative impact on productivity of Montagu's harrier nests and should be given high consideration when designing protection measures. In fact, the effectiveness of the removal and relocation intervention in Spain could be further increased by placing a protective fence around the nests. This also likely applies to the buffer. In this case, a protective fence may render the buffer measure one of the most effective among all options, as results from France (**chapter II**) and other countries, such as The Netherlands, indicate (Koks and Visser 2002).

At present, measures like the fenced buffer and fenced relocation are likely to provide a quick and operationally feasible solution. However, it is also important to note that nest protection measures should only be used and regarded as temporary solutions. A wider landscape management approach is in fact recommended in order to ensure sustainable population persistence in the long term. This applies for the conservation of Montagu's harrier in Spain as well as France and likely elsewhere (**chapter III** and **II**, respectively). Although in the farming context agri-environment schemes may represent a valuable management option at the landscape level, they also suffer from mixed success and require continuous financial support which will likely render them unsustainable in the long run (see e.g. de Snoo et al. *in press;* Kleijn et al. 2006). Instead, working on the socio-psychological level to try to better understand and thus influence farmers' behavior and motivation towards sustainable farming practices is important. It may produce a more durable and financially sustainable change that cannot be achieved through market-based means (de Snoo et al. *in press*). The evidence from the successful voluntary inexpensive conservation program run in North Karelia (**chapter I**) runs in support of this view. On the contrary, if payments become the rule, then the system may be artificially supported and quickly overruled by market values and thus become increasingly dependent on monetary inputs (de Snoo et al. *in press;* Vatn 2010). While implementing a more sustainable and long lasting solution to conservation problems in farmland, which may take years if not decades, it is important to preserve what is still left at present. In this light, the evaluation studies presented in **chapter I**, **II** and **III** provide the evidence-base for taking immediate action with high chances of success.

4.3. Effectiveness of compulsory measures

Coercive top-down means, mostly through the institution of protected areas as well as national and international legislation, have been and will constitute the cornerstone of nature conservation efforts worldwide (Hansen and DeFries 2007). However, the success of protected areas has been recently questioned (Ferraro and Pattanayak 2006), while that of legislation has rarely been assessed (but see e.g. Burkhart et al. 2012; Ferraro et al. 2007; McLean et al. 1999). These two top-down approaches to conservation often entail high financial and societal costs (related to public acceptance), and therefore it is very important that their existence is justified and supported by the benefits they provide to biodiversity. In this context, evaluations of the effectiveness of these measures are particularly needed.

In the archipelago and coastal areas of south-western Finland, we show that protected areas (a large and fragmented National Park and a set of small and scattered single protected areas) do not provide any apparent benefit to breeding white-tailed eagles when compared to available unprotected nests in the area. This conclusion holds at least for the period of study considered (1998 - 2010; see **chapter IV**) and as long as there is no total destruction of the habitat surrounding unprotected nests. The species was in fact found to breed as frequently and successfully at nests within protected areas as well as in unprotected land (Figure 6). This result is most probably explained by the low selectivity of the species in terms of nesting habitat requirements. We show that white-tailed eagles can breed in very different nesting environments in terms of the type of forestry practice applied around the nest, its visibility and its spatial relationships with possible disturbance features (such as roads and buildings; see **chapter IV**).

The apparent lack of influence of infrastructures and forest management on breeding white-tailed eagles is likely due to the low disturbance levels in the study area, especially at the beginning of the breeding season. This result is also due to the fact that the species in Northern Europe can make use of a variety of

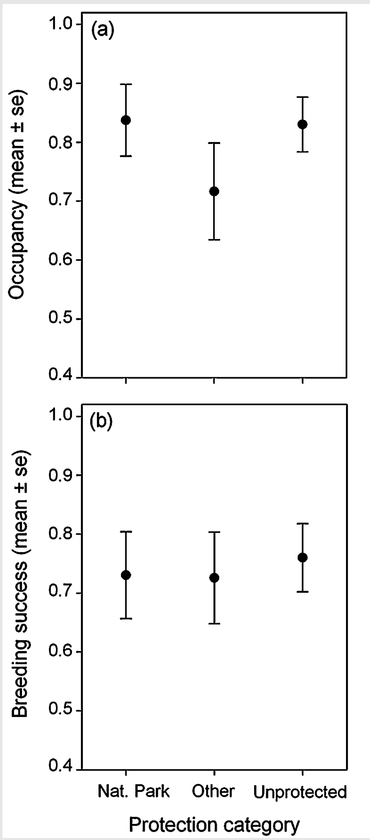

Figure 6. Predicted (a) nest occupancy and (b) breeding success (the probability of an occupied nest to produce at least one fully grown young) of white-tailed eagles between three different levels of protection: National Park (Nat. Park), private protected and government owned areas (Other), no protection (Unprotected). (Reproduced from Santangeli et al. Animal conservation, in press).

different habitat types for nesting (Dahl et al. 2012; Helander and Stjernberg 2002). This latter trait, coupled with the almost total absence of persecution in the studied population during recent years, may enable the species to make increasing use of man-altered landscapes. It should be noted, however, that here we used proxies of disturbance based on a static situation where we could only show that there is no obvious impact of already altered landscapes on nesting eagles. More research is thus required to assess the direct and immediate consequences of forest cutting or infrastructure development in the nest surroundings.

On the other hand, for more strict habitat-specialist species, like the Siberian flying squirrel, we show that habitat protection implemented according to guidelines (Anonymous 2004) enforcing Finnish legislation (Nature Conservation Act 1096/1996) was ineffective (**chapter V**). We found that flying squirrels largely disappeared after the forest where they breed and/or rest was clear-cut and a small wooded patch was retained as required by the law (Figure 7).

This case clearly indicates that the legislation was enforced by means of too shallow restrictions that do not meet the targets imposed by the EUs Habitats Directive (i.e. prohibit destruction or deterioration of sites where Annex IV species occur). Protection of flying squirrel habitat may entail high costs to the society, because the forests where it occurs are valuable for timber production and often privately owned. Thus, the owners are not particularly willing to set them aside for conservation, especially if this decision is imposed from the top. Under this conflicting situation between wildlife conservation and resource extraction, finding trade-offs which would allow for sustainable development is imperative (McShane et al. 2011). However, for this to take place, it is crucial that policy decision-makers have a clear understanding of, and openly acknowledge, the resulting costs, gains and losses of any possible decision they take. This was unfortunately not the case when the guidelines to protect flying squirrel habitat have been issued in Finland (Anonymous 2004). The size of the compulsory area (0.03-0.07 ha of forest) to be retained in order to prevent habitat deterioration for the species, was not supported by any scientific evidence. Such situations are not uncommon (Brosnan and Groom 2006; Burkhart et al. 2012). Often when decisions are to be made to solve conflicting situations, economic interests are prioritized over nature conservation. Our results strongly call for a revision of current guidelines in order to allow for effective protection of the species in Finland (**chapter V**).

These two case studies (**chapter IV** and **V**), although limited in the time period and geographic extent considered, clearly show that evaluations of the effectiveness of conservation actions can reveal unexpected but important outcomes for best allocating limited conservation resources. The results from both studies indicate that current conservation actions for the two species examined should be revised. Beside the clear case of the ineffective legislation for protecting flying squirrel sites, an update is also needed in the way that conservation resources are spent for the white-tailed eagle. For this, protection measures could be implemented on a totally voluntary and inexpensive basis. This is justified by the result that the species can thrive also in unprotected land (**chapter IV**), and therefore there is no need for additional societal and financial costs.

Legislation in Europe has been found to be effective at addressing direct threats to species (such as persecution, but see however

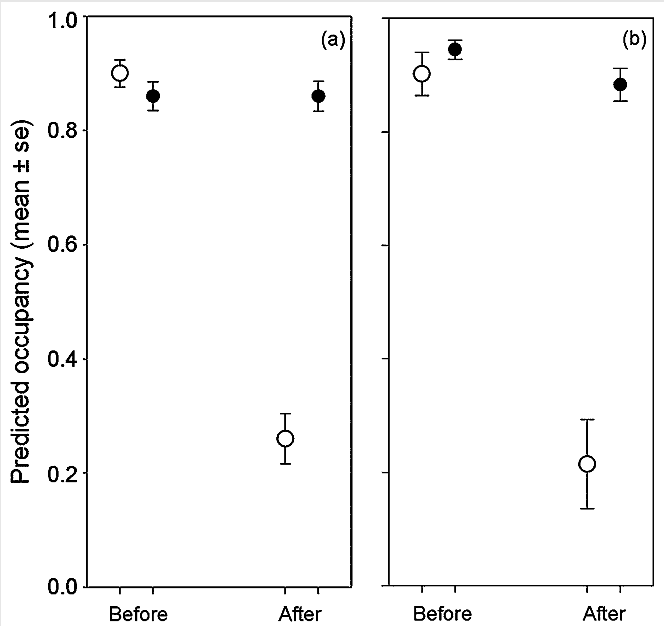

Figure 7. Predicted flying squirrel occupancy at the (a) forest and (b) nest box level for the periods before and after the forest cut at control (un-cut areas; filled symbols) and cutting (where forest was cut according to guidelines; open symbols) sites. (Reproduced from Santangeli et al. 2013. Biological conservation 157:237-244).

e.g. Amar et al. 2012; Smart et al. 2010), while indirect threats (e.g. changes in land use) have been often harder to revert (Burfield 2008; McLean et al. 1999). These latter threats have been often addressed through the designation of protected areas, which, although effective in many cases, don´t always yield the expected outcomes owing to the social context in which they are instituted and the criteria with which they are designated (Joppa and Pfaff 2009; Laurance et al. 2012a; Pressey 1994; Walker 2009). Therefore, an assessment of the effectiveness of implemented measures is crucial in order to understand what works and what should be changed within an adaptive management framework for conservation (Margoluis and Salafsky 1998; Salafsky et al. 2002). Within this dynamic process, decisions are ultimately made and updated based on a more balanced trade-off between nature conservation and human development (Hirsch et al. 2010; McShane et al. 2011). However, at the policy level, the decision-making process is often unbalanced towards economic interests, and this is commonly justified by a lack of convincing scientific evidence about the effects of specific actions (Brosnan and Groom 2006). Given these premises, providing solid and convincing evidence, such as that presented in **chapter V**, will likely leave little space for ambiguity at the decision-making stage, and this should ideally lead to taking more balanced and sustainable decisions. However, given the difficulties in solving conflicting situations, like that over the conservation of flying squirrels in Finland, an approach that would integrate top-down with bottom up means and working solutions together with landowners will be one of the key to ensure long term success. For this to take place, a better understanding of the psychology driving motivation of landowners to apply conservation measures is strongly needed (Clayton and Myers 2009; Saunders 2003; Tikkanen et al. 2006; Vatn 2007).

5. CONCLUSIONS AND IMPLICATIONS FOR CONSERVATION

This thesis makes a small contribution towards filling the existing large divide between conservation science, practice and policy, by addressing relevant conservation issues. It also sheds some light into the potential of voluntary approaches for conservation that have been so far relatively overlooked.

A large share of biodiversity of high conservation value nowadays locates on private lands that are under some forms of production regimes (Millennium Ecosystem Assessment 2005). Therefore, conservation in these socio-ecological landscapes can only reach long term successes if a multidisciplinary approach is undertaken (Cooke et al. 2009). This would ultimately allow achieving sustainable development without generating, or eventually solving, conflicts between people and biodiversity conservation. Unfortunately, this is too seldom achieved because of a large gap between conservation policy and practice (Sutherland et al. 2012). However, communication is also lacking between conservation practitioners and researchers, despite their common goal. This divide is due to conservation research within academia often asking questions that are not relevant to practitioners or providing solutions that are not directly applicable within a complex and multifaceted socio-ecological landscape (Gibbons et al. 2011; Laurance et al. 2012b; Sutherland et al. 2011b). The lack of communication and integration between different levels of conservation actors and disciplines is causing large inefficiencies in the way that conservation resources are used. This is inadmissible in a time of massive biodiversity crisis and scarcity of conservation resources.

The individual chapters comprising this thesis have been drawn around conservation issues that were brought up from the bottom (e.g. from practitioners), or were of high relevance to inform conservation policy. In each study we made use of monitoring data to evaluate the effectiveness of past and currently implemented management actions. This step is rarely undertaken but badly needed in conservation (Ferraro and Pattanayak 2006) as it provides the evidence upon which conservation decisions can be made or revised (Sutherland et al. 2004).

On a general level, one of the main conclusions that can be drawn from this thesis is that evaluating the effectiveness of past and currently implemented conservation interventions may reveal very interesting and unexpected outcomes. The information derived from such assessments is useful for updating the allocation of conservation resources within an adaptive management framework (McCarthy and Possingham 2007; Salafsky et al. 2002). Specifically, from the single chapters of this thesis we can conclude that, after their evaluation, some expensive and coercive management interventions may result unnecessary (**chapter IV**), some, like legislation, may not be effective at achieving their goal (**chapter V**) while others, like inexpensive voluntary approaches, can achieve important results with very limited resources (**chapter I**). Relevant outcomes for applied species management can also be revealed when multiple interventions are compared, as it is the case for protection measures of Montagu's harrier nests. In France, it was clear that the two most effective interventions (fenced buffer and fenced relocation) were those allowing for the simultaneous protection from harvesting destruction and predation (**chapter II**). Interestingly, in Spain one of the most commonly adopted measures (the buffer) was not as effective as two other means, such as relocation or removal and harvest delay (**chapter III**).

Another important conclusion that this thesis highlights concerns the underlying approach to address conservation in private land under production regimes. Obviously, the case studies comprising this thesis are limited in space and time, and thus the resulting inferences are not generalizable to broader contexts. Nevertheless, the results still provide interesting outcomes and largely support the growing body of evidence suggesting that conservation must not neglect the social dimension of the landscape in which it is implemented (Knight et al. 2010; Miller et al. 2011; Saberwal and Kothari 1996). The successful example of inexpensive voluntary conservation implemented with the active participation of forest owners in North Karelia (**chapter I**) suggests that bottom-up and inexpensive approaches can be useful. They provide a valuable tool that can complement traditional and well established conservation measures for nature protection in private land. Voluntary inexpensive approaches, which strongly rely on the self-motivation of individuals, have been largely overlooked in the past. However, they were recently proposed as a more economically sustainable and longer-term solution for biodiversity conservation in farmland compared to market-based approaches requiring continuous monetary inputs (de Snoo et al. *in press*). On the other hand, when operating under scarcity of resources and in heterogeneous social-landscapes, it is also important that practitioners know the relative effectiveness of alternative interventions available within the conservation toolbox. This knowledge will ultimately allow taking quick and effective decisions based on the social context and landscape characteristics at the local scale. The studies on nest protection for the Montagu's harrier (**chapter II** and **III**) go one step to this direction.

Finally, evaluating conservation interventions is very challenging and often requires large datasets spanning long enough time to detect any impact and including many variables depicting possible confounding effects (Ferraro and Pattanayak 2006; Jones 2012). However, such large datasets are becoming increasingly common, and thus more evaluation studies are being reported (see e.g. Howe and Milner-Gulland 2012a; Laycock et al. 2009; Laycock et al. 2011). To ensure that limited resources for conservation produce the best possible outcome, more evaluations are still required, and thus more analysts should be involved in this field.

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This PhD was almost entirely based on data collected during years or decades by the massive effort of tireless and excited nature and conservation volunteers. To all of them goes my deepest respect and admiration. To collect all such data on my own, I would have needed quite many lives! My most sincere appreciation also goes to all those landowners that have happily participated to the conservation programs I studied, often giving up some small parts of their income to set aside portions of their land for conservation. The positive spirit and motivation of these people leaves a great hope for the future of nature conservation.

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