

# FUND RAISING FOR SPECIES PROTECTION IN NATIONAL PARKS: LIMITATIONS AND OPPORTUNITIES OF NATURE BASED TOURISM

Doris A. Behrens<sup>1,2</sup>, Birgit Friedl<sup>3,4,\*</sup> and Michael Getzner<sup>2</sup>

<sup>1</sup> ORDYS, Department of Mathematical Methods in Economics, Vienna University of Technology, Argentinerstr. 8/105-4, A-1040 Vienna, Austria

<sup>2</sup> Department of Economics, University of Klagenfurt, Universitaetsstr. 65–67, A-9020 Klagenfurt, Austria  
email: {doris.behrens, michael.getzner}@uni-klu.ac.at

<sup>3</sup> Department of Economics, University of Graz, Universitaetsstr. 15, A-8010 Graz, Austria

<sup>4</sup> Wegener Center for Climate and Global Change, University of Graz, Leechgasse 25, A-8010 Graz, Austria  
email: birgit.friedl@uni-graz.at

\* corresponding author

## Abstract

Conservation budgets are – in times of fiscal austerity – scarce, and many administrations of protected areas aim for different sources of funding besides the public budgets. Tourism to protected areas can help in opening up new sources of funding. Improving visitor infrastructure can attract more visitors to a protected area who are willing to pay for their recreation benefits. Directly, visitors spend money on parking and entry fees. Indirectly, increased awareness and education leads to higher WTP for species on the basis of non-use values. While budget-generating, tourism also brings ecologically negative impacts to a protected area. In this paper, we discuss these two-edged effects of tourism by means of bioeconomic model which frames the interaction of species, their (joint) habitat, and humans in a particular ecosystem. The implications of the endogenous conservation budget and its allocation towards endangered species are discussed analytically in a general context, suitable for complex species-habitat-visitor interactions, and underlined by a case study for the rock partridge population in the Mallnitz Tauern Valley (National Park Hohe Tauern, Austria). On the basis of our numerical example, realistic empirical parameters and a GIS model of the region, we identify policies that combine both higher visitor numbers and contribute to species protection in a cost-effective way. A policy-mix of visitor infrastructure improvements and habitat creation performs best in terms of combined effects regarding recreation, conservation and funding.

Keywords: bioeconomic model, species conservation, tourism, optimal policy mix.

JEL codes: C61; Q26; Q28

## 1. Introduction

In Alpine regions the protection of charismatic species such as the golden eagle or the bearded vulture is a challenging but well-funded task (Pachlatko, 1991; Robin *et al.*, 2004; Frey, 1999). As compared to these charismatic birds, less popular species derive less attention and often smaller conservation budgets (e.g., Metrick and Weitzman, 1998; Dawson and Shogren, 2001; Ando and Getzner, 2005). The rock partridge (*Alectoris graeca*, listed in the EU Flora Fauna Habitat directive)<sup>1</sup> can be regarded as paradigm for such a ‘non-charismatic species’. Therefore, while the public does neither attribute value to the protection of the rock partridge, from a scientific point of view the partridges can be regarded as an indicator for natural alpine habitats largely untouched by human use.

As a consequence of its low public appreciation, visitors to the park might not particularly be in favor of visitor restrictions guaranteeing the survival of the rock partridge necessary to fulfill the EU Birds directive’s requirement of non-declining population numbers of the rock partridge. However, at least indirectly, visitors are important for the protection of the rock partridge: Considering that national parks are highly dependent on federal subsidies,<sup>2</sup> public expenditures have to be justified to be important for the general public. Thus, the more visitors ‘vote by their feet’ for protected areas, the more willing are federal authorities to supply for funding.

Public expenditures on wildlife conservation should not only be supported by public opinion but should be cost-effective, too. Accordingly, the problem of how to choose networks of conservation reserves to minimize the cost of accomplishing a conservation goal (or maximize the conservation benefits that can be attained for a given level of cost) has been analyzed by several authors (e.g. Ando *et al.*, 1998; Parks, Kramer, Heimlich, 1995; Polasky, Camm, and Garber-Yonts, 2001; Costello and Polasky, 2004; Ando and Getzner, 2006). However, Wätzold and Schwerdtner (2005) point out that observed patterns of biodiversity conservation policy may be far from cost-effective.

In the context of protected area management, the type of human damage caused to the ecosystem is a side-effect rather than an explicit activity such as hunting. While multi-species models with harvesting typically neglect wildlife-related use and non-use values to visitors and are, therefore, less suitable for the present research question, some authors addressed wildlife conservation and its (negative) economic consequences (see, e.g., Conrad and Salas, 1993; Bulte and van Kooten, 2002;

<sup>1</sup> Rock partridges only occur in the Alps and mountains of Italy and the Balkan. According to BirdLife International (2004, 2005) the Austrian breeding population size is estimated to 900-1,200 pairs.

<sup>2</sup> Annual federal contributions are about €10.11m for all Austrian national parks, €2.6m for the *Hohe Tauern* national park; total annual public expenditure amount to about €26m (ITR, 2001).

Shogren *et al.*, 2003; Hoekstra and van den Bergh, 2005; Skonhoft, 2005; Behrens and Friedl, 2006). The present paper contributes to this field by developing an analytical food chain model of a non-charismatic species, its habitat, and the interaction with park visitors in order to investigate the cost-effectiveness of different wildlife conservation and visitor policy measures. We explore the multiple trade-offs between visitor preferences and the protection of non-charismatic species from the point of view of the national park administration. This is accomplished by determining endogenously the (additional) conservation budget by the visitors' aggregate willingness to pay to conserve and improve biodiversity. Thus, conservation depends on the number of visitors, the state of the ecosystem and its change of ecological quality. To illustrate our model and to evaluate its ability of explaining the visitor-species interaction in real-world protected areas we use data for the rock partridge population in a particular area located in the *Hohe Tauern* national park (Austria). Based on investigations of the willingness to pay for conservation and on the cost structure of the interventions, we determine the optimal ecological management policy for the case study and illustrate the influence of the benefit criterion on the optimal policy.

The paper is structured as follows. Section 2 starts with a description of the food chain model augmented by the impacts of visitors and the modeling of conservation and tourism policies. As a reference, we investigate the equilibrium of this bioeconomic model if policies without taking account of visitor or conservation policies in Section 3. Section 4 aims to identify an 'ecologically neutral' policy mix (increasing visitor demand together with supporting the species of concern) which is associated with preserving the population size of the non-charismatic species at the reference equilibrium and maximizes the net benefits for the park administration. Suggestions for further research and the derivation of policy recommendations for practical decision-making in conservation conclude the paper.

## 2. Model description

In this section, a (dynamic) intertemporal bioeconomic model capable of describing the interaction of a non-charismatic species with its habitat and tourism in a protected area (PA) is developed. While the model is based on Friedl and Behrens (2006), it provides extensions along two lines. The first is that visitor demand responds to visitor infrastructure and the state of the ecosystem. The second modification is that the species under consideration is non-charismatic in a sense that it is small, hard to see and not particularly cute. One consequence of that is that ecosystem interactions can be approximated by a food-chain model (replacing the predator prey model in Friedl and Behrens, 2006).

The protected area under consideration is not a game park and visitors, on the contrary, come for hiking and other non-consumptive wildlife recreation.<sup>3</sup> However, visitors have a detrimental impact on the ecosystem, either directly by e.g. disturbing species or habitat destruction, or indirectly through the demand for visitor infrastructure such as hiking trails, picnic sites, parking areas and shelters. For the latter, the non-charismatic species is impaired by destruction or fragmentation of its habitat. Moreover, visitors are attracted by landscape (which is ‘untouched’ and therefore suitable for serving as habitat of the species under consideration), the quality of visitor infrastructure (trails, picnic areas, nature trails, lodges, etc.), but also by wildlife found there (we assume that the species serves as a proxy for that). Each component of the bioeconomic model will be described in turn, starting with the ecological system impaired by visitors.

## 2.1 A food chain model augmented by the negative impact of tourism

Usually, non-charismatic species such as the rock partridge are not large predators, and therefore, the modeled species  $S(t)$  does not impair its habitat  $H(t)$  (Hafner, 1994). For obvious reasons, a given habitat area cannot ‘grow’. However, the protection status and the actual area size protected can increase, but this process cannot proceed infinitely due to competition with other types of land use. These observations together motivate the modeling of habitat dynamics by means of a logistic function. Thus, the area suitable as habitat (or the appealing landscape, seen from the viewpoint of visitors) grows towards its maximum possible extent (i.e., its carrying capacity  $\omega$ ).<sup>4</sup> Accordingly, Eq. 1 can be used to describe the habitat’s growth rate  $g(t)=g(H(t), U(t))$  embodying the inverse relationship between habitat growth and the number of visitors  $U(t)$ :

$$g(H(t), U(t)) = \alpha \left( 1 - \frac{H(t)}{\omega(1 - a(U(t)))} \right) \quad (1)$$

with

- $U \geq 0$  number of visitors in percent of the ‘baseline level’  $U_0 = 1 = 100\%$ ,
- $H > 0$  habitat area in  $\text{km}^2$ ,
- $a > 0$  natural growth rate of the habitat,
- $\omega > 0$  pristine carrying capacity.

---

<sup>3</sup> According to Duffus and Dearden (1990), non-consumptive wildlife recreation refers to recreational activities that are not harming wildlife on purpose, such as bird-watching, nature walks, photography or viewing in parks.

<sup>4</sup> Of course, an area cannot grow as land is limited by physical constraints. In the current context, we take the whole area that is in principle suitable for a habitat of the rock partridge, and let the habitat increase within these limits as the current habitat does not consume all the area available.

Eq. 2 captures the negative impact of visitors on the pristine carrying capacity ( $\omega$ ).<sup>5</sup> The percentage value of this modeled damaging impact,  $a(U(t)) \in [0,1]$ , is zero only in absence of tourism. Assuming that the marginal effect ( $\partial a / \partial U$ ) is increasing with the number of visitors, we implement a quadratic function for the percentage reduction of the carrying capacity  $\omega$ :

$$a(U(t)) = \rho U(t)^2 \in [0, 1],^6 \quad (2)$$

with

$2\rho > 0$  marginal percentage reduction of carrying capacity  $\omega$  (per additional visitor).

A standard feature of food chain models is that the species depending on the habitat grows logistically, too. Its carrying capacity is restricted endogenously by the supply of suitable breeding area ( $\beta H(t)$ ) which is usually smaller than the habitat  $H(t)$ :

$$f(H(t), S(t)) = \gamma \left( 1 - \frac{S(t)}{\beta H(t)} \right) \quad (3)$$

with

$S > 0$  number of breeding pairs of rock partridge population,

$\beta \in [0, 1]$  conversion rate of habitat into carrying capacity of non-charismatic species,

$\gamma > 0$  natural growth rate of the non-charismatic species population.

Visitors  $U(t)$  are attracted by the existing diversity of ‘untouched’ landscapes, ecosystems, animal and plant species, including rare/threatened animals living therein, and by the quality of visitor infrastructure (hiking trails, picnic areas, nature trails, lodges, availability of information, vista points etc.). Thus, the number of visitors  $U(t)$  at time  $t$  is determined by a Cobb-Douglas-type<sup>7</sup> ‘visitor demand function’ depending on the ecosystem conditions  $(H(t), S(t))$  and visitor infrastructure  $v > 0$ :

$$U(t) := U(H(t), S(t)) = v H(t)^\mu S(t)^{1-\mu}, \quad (4)$$

with

---

<sup>5</sup> Since the rock partridge breeding areas are located in direct vicinity to the existing hiking trail network, the rock partridge population has to ‘compete’ with visitors for the landscape serving as its breeding grounds and retreat area. Therefore, it is suitable to model visitor damage by a reduction in the area suitable as habitat for the partridge population.

<sup>6</sup> Since Eq. 2 is usually not limited to values in the unit interval, we parameterize and truncate the function appropriately.

<sup>7</sup> Note that the choice of the functional form is merely driven by empirics. A demand function linear in both arguments ( $H$  and  $S$ ) yielded counter-intuitive results, such that visitors were deterred by partridges (this were suitable if we described visitors’ reaction to the existence of bears or other dangerous species but not for the unobservable partridge).

- $\nu$  availability of visitor infrastructure, e.g. hiking trails,
- $\mu$  elasticity of the habitat  $H(t)$  with regard to the attraction of visitors by the habitat.

## 2.2 The bioeconomic model with conservation and visitor policies

As argued before, we are basically interested in developing strategies for PA management that allow increasing (or at least maintaining) the number of visitors without severely damaging the bio-economic system. This can be accomplished by a policy mix combining measures for the protection of the ecosystem and for visitors. The ecosystem can be protected by e.g. habitat creation or improvement, or by species restocking while visitors can be attracted by additional visitor infrastructure.<sup>8</sup> *HABitat* creation implies that the area of suitable habitat for the non-charismatic species is increased. This improves the conversion rate from habitat into species  $\beta$ , i.e. the endogenous carrying capacity for  $S$ , in (3) by a certain percentage  $(1+\lambda)$ , as given by (5a).

On the other hand, visitor infrastructure improvement (called *REG* for regulation) helps to create an atmosphere of supporting the existence of the PA by the local population but has a negative impact on both  $H$  and  $S$ . Thus, changes in visitor infrastructure (*REG*) can be integrated by increasing the visitor infrastructure parameter in the visitor demand function (4) by simply modifying the number of visitors by a certain percentage,  $(1+\psi)$ , as given by (5c). Positive values of  $\psi$  correspond to visitor infrastructure improvements and negative ones to visitor access restrictions, e.g. during sensitive periods.<sup>9</sup>

Describing the effects of increasing visitor infrastructure  $\psi$  and habitat creation  $\lambda$  on the ecosystem in such a way yields the following two-stage continuous-time bioeconomic model

$$\dot{H}(t) = \alpha \left( 1 - \frac{H(t)}{\omega (1 - a(U(t)))} \right) H(t), \quad H(0) > 0, \quad (5a)$$

$$\dot{S}(t) = \gamma \left( 1 - \frac{S(t)}{\beta(1+\lambda)H(t)} \right) S(t), \quad S(0) > 0, \quad (5b)$$

$$U(t) = \nu(1+\psi)H(t)^\mu S(t)^{1-\mu}, \quad U(0) > 0. \quad (5c)$$

System (5a)-(5c) has been fully parameterized for the case study of the rock partridge population situated in the *Mallnitz Tauern* valley (*Hohe Tauern* national park, Austria) and the hiking visitors

---

<sup>8</sup> Habitat creation is understood to comprise all measures that increase the quality of the habitat (e.g. by means of changing vegetation) and the size of the area by designating larger areas as the core zones of a national park.

found there. The rock partridge (*Alectoris saxatilis graeca*) is a game bird living in a high mountain habitat largely untouched by human use, and typical manmade sub alpine and mountain pasture ranges in hilly areas. The breeding grounds are between 1,780 m and 2,040 m above sea level, just in the ecosystems near the tree line (Hafner, 1994). The rock partridge is vulnerable to visitors either during breeding season (when hikers disturb nesting and feeding) or during winter rest (when partridges are disturbed by skiers).<sup>10</sup> A detailed description of data sources and calibration procedure can be found in Appendix A.2, the respective values are captured in Table 1.

*Table 1: Parameter values for the rock partridge in the Mallnitz Tauern valley*

Parameter	Value	Description
$\alpha$	0.4621	Growth rate of the size of the landscape (= habitat), with the limits of growth given by pristine landscape
$\beta$	0.3843	Conversion rate of habitat into carrying capacity of rock partridge
$\gamma$	0.6200	Annual net growth rate of the rock partridge (Hafner, 1994)
$\omega$	41.630	Pristine carrying capacity of the habitat (= total area of <i>Mallnitz Tauern</i> valley)
$\nu$	0.0368	Scaling parameter in visitor demand function
$\mu$	0.9500	Elasticity of habitat (landscape) in visitor demand function (= significance of the habitat for attracting visitors, compared to the species)
$\rho$	0.1303	Marginal reduction of carrying capacity of habitat due to visitors
$H(0)$	28.37	Size of rock partridge habitat in square kilometers at time $t=0$ (Behrens et al., 2006)
$S(0)$	12	Number of breeding pairs at time $t=0$ (Behrens et al., 2006)

### 2.3 Benefits and costs of conservation and visitor policies

In order to evaluate the different policy options from the point of view of the park administration, we consider benefits in terms of revenues generated by additional visitors (relative to  $U_0$  and  $S_0$ ), by either out-of-pocket expenses on visitor facilities or by donations of visitors to species protection measures. Accordingly, the net benefit ( $NB$ ) is calculated as the discounted stream of benefits of visitors (use-values), the indirect benefit from an increase in the number of species  $S$  (non-use values), and the costs of additional visitor infrastructure and of habitat creation, respectively:

---

<sup>9</sup> Note that the availability and targeted dissemination of information about sensitive areas of the nature reserve yields a different effect as increases in infrastructure do. This form of control would not necessarily alter the number of tourists but reduce their damage to the ecosystem.

<sup>10</sup> Since the impact in summer is much more serious than during winter, we restrict our analysis to this case only and describe the influence of visitors as disturbing the habitat dynamics (i.e., the suitable breeding area is reduced).

$$NB_{UV+NUV} = \int_{t=0}^T [\kappa U(t)(S(t) - S_0) + \varepsilon(U(t) - U_0) - (\theta\psi^2 + \phi\lambda^2)] e^{-rt} \quad (6)$$

where

- $\varepsilon$  average infrastructure expenditures in thousand Euros,
- $\kappa$  average willingness to pay (=donation) per breeding pair in thousand Euros
- $\theta$  cost of providing additional visitor infrastructure (associated with an increase in visitor numbers by 1%)
- $\phi$  cost of increasing the habitat by 1%

The first term in (6) refers to the aggregate donations by all visitors generated by an increase in the population size of the non-charismatic species (relative to  $S_0$ ) and the second term to visitor spending related to visitor infrastructure due to an increase in the number of visitors (relative to  $U_0$ ) yielding additional park revenues. Assuming that improvement of visitor infrastructure is subject to decreasing returns to scale, we associate quadratic cost with the provision of additional visitor infrastructure ( $\psi$ ).<sup>11</sup> The fourth term, the cost of habitat creation, is also modeled to develop in a quadratic manner, where  $\lambda=0$  is associated with the status quo. As a special case, we will consider in Sections 4.1 and 4.2 an alternative measure for net benefit that takes only account of visitor benefits but not of benefits associated with an increase in species numbers, thus  $\kappa=0$ .

Table 2: The policy parameters values for the rock partridge in the Mallnitz Tauern valley

	Value	Description
$t$	10	Length of planning horizon
$r$	0.04	Discount rate
$\kappa$	0.0017	Average willingness to pay for an additional rock partridge breeding pair
$\varepsilon$	0.0018	Average visitor infrastructure expenditures
$\theta$	11.6474	Cost parameter of increasing visitor infrastructure
$\phi$	633.890	Cost parameter of habitat creation

---

<sup>11</sup> This does not (only) come from the fact that setting up new trails becomes more and more inefficient, but from a crowding effect of visitors (i.e., additional trails and additional visitors do not behave proportionally). If the level of maintenance work falls below its baseline level, less hiking trails are available. This reduces maintenance cost for  $\psi < 0$  (since the  $sgn$  function is responsible for the negative sign,  $sgn[\psi] = -1$ ), and the additional costs are thus costs reductions.

Table 2 gives the parameter values assigned to the net benefit functions (6) for the case study (see Appendix A.2 for the calibration). To put these numbers into perspective, the current aggregate WTP is €39,447 per breeding pair (total of 22,910 visitors), while an additional breeding pair costs approximately €44,545 (evaluated by the cost of creating sufficient additional habitat for an additional breeding pair). Thus, income generated by additional visitors through new visitor infrastructure is essential to cover these costs.

### 3. The long run equilibrium behavior

#### 3.1 The bioeconomic equilibrium

By using (5c) in (5b) and setting the time derivatives of (5a) and (5b) equal to zero, we gain two isoclines in  $H, S$  space, see Appendix A.1. In the relevant subsection of the phase space  $\{(H, S) | 0 < H \leq \omega, 0 < S\}$ , the model exhibits a unique bioeconomic equilibrium:

$$\{\hat{H}, \hat{S}\} = \left\{ \frac{2\beta^\mu \omega}{\beta^\mu + \sqrt{\beta^{2\mu} + 4\beta^2 \nu^2 \rho(1+\psi)^2 \omega^2}}, \frac{2\beta^{\mu+1} \omega(1+\lambda)}{\beta^\mu + \sqrt{\beta^{2\mu} + 4\beta^2 \nu^2 \rho(1+\psi)^2 \omega^2}} \right\}, \quad (7)$$

This equilibrium always exists for  $\beta > 0$  and does not depend on the growth rates  $\alpha$  and  $\gamma$  (as a consequence of using a food chain model, not a predator-prey model). As can be seen from (7), additional visitor infrastructure ( $\psi$ ) affects the bioeconomic equilibrium (both  $H$  and  $S$ ) in a negative way while habitat creation ( $\lambda$ ) affects  $S$ , but not  $H$ , in a positive way.

As a point of reference, we investigate the bioeconomic equilibrium if no additional measures are undertaken, i.e. we set  $\psi=\lambda=0$ , and refer to this solution as the ‘reference equilibrium’. This results in  $\hat{H} = 33.94 \text{ km}^2$ ,  $\hat{S} = 13$  breeding pairs, and visitors  $\hat{U} = 1.19$  for the base case parameter values (given by Table 1). Thus, the current state of the *Mallnitz Tauern* ecosystem ( $H(0) = 28.37 \text{ km}^2$ ,  $S(0) = 12$ ,  $U(0) = 1 = 100\%$ ) is already ‘quite close’ to its bioeconomic equilibrium state. The size of habitat increases by almost 20% yielding a comparable increase in visitor demand by 19% and an additional breeding pair.

In order to investigate the responsiveness of the bioeconomic equilibrium values of  $H$ ,  $S$ , and  $U$ , Table 3 summarizes the changes in the equilibrium quantities for a 1%-change in the size of the respective parameter value. An increase in the visitors’ appreciation of the habitat (by increasing  $\mu$ )

decreases the equilibrium values for the ecosystem but increases the equilibrium number of visitors. A similar result occurs for parameter  $\nu$  reflecting the effect of additional visitor infrastructure (supply of trails, picnic areas, exhibitions) on the number of visitors. As an effect of the quadratic visitor damage function, an increase in the number of visitors leads to a smaller percentage reduction in  $\hat{H}$  and  $\hat{S}$  than the increase in  $\hat{U}$ . The scaling factor  $\rho$  yields, however, a different kind of behavior. If  $\rho$  increases (= the marginal damage of visitor increases) the ecosystem suffers *and* the number of visitors declines.

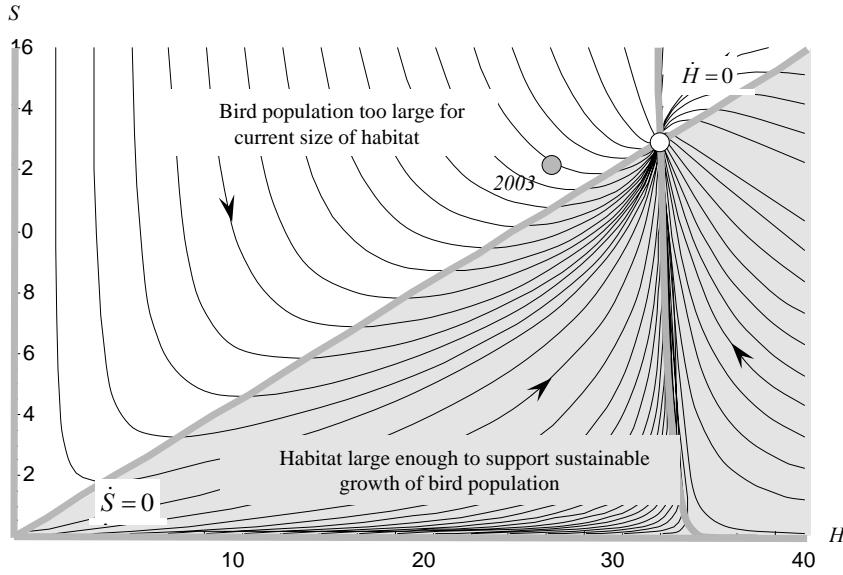
*Table 3: Elasticities (+ 1%) of equilibrium quantities*

	$\hat{H}$	$\hat{S}$	$\hat{U}$
$\beta$	- 0.01%	+ 0.98%	+ 0.03%
$\omega$	+ 0.69%	+ 0.69%	+ 0.69%
$\nu$	- 0.31%	- 0.31%	+ 0.69%
$\mu$	- 0.28%	- 0.28%	+ 0.63%
$\rho$	- 0.15%	- 0.15%	- 0.15%

### 3.2 The bioeconomic system away from the (reference) equilibrium

For the base case parameter values (see Table 1) and setting  $\psi=\lambda=0$ , Figure 1 depicts the isolines for  $H$  and  $S$ , as well as the trajectories approaching the bioeconomic equilibrium (identified by the white circle located at the intersection of the isolines in the interior of the ecologically relevant region of our model). The shape of the trajectories indicates that for the base case parameter values the equilibrium is a stable node, a result that can be confirmed by investigating the Jacobian of the food chain model evaluated at its equilibrium (see Appendix A.1).

Figure 1: Phase diagram for base case parameter values plus 2003 data point



Let us investigate the  $H, S$  phase plane in more detail. For any point above the  $\dot{S} = 0$  isocline (the grey line with positive slope), the  $S$  population is declining, while below it is increasing (grey shaded area). Accordingly, points to the left of the  $\dot{H} = 0$  isocline (the steep grey line) lead to an increase in the size of the habitat while points to the right of it lead to a decrease. Thus, for any point above of the  $\dot{S} = 0$  isocline and to the left of the  $\dot{H} = 0$  isocline the transition towards the bioeconomic equilibrium is described by a trajectory that initially implies a decline in the number of species until the trajectory surpasses the  $\dot{S}$ -isocline. After that point, the habitat as well as the species increases towards the bioeconomic equilibrium.

Moreover, for the model parameterization of the *Mallnitz Tauern* valley model outcomes are highly inelastic in equilibrium as well as in the transition phase (see Table 3 and Table 4) with respect to parameter changes. While the bioeconomic equilibrium does not depend on the intrinsic growth rates of habitat and species, the transition paths are influenced by the values of  $\alpha$  and  $\gamma$  (the accumulated effect over the first ten years (which is equivalent to the length of planning horizon) are given in Table 4).<sup>12</sup> Increasing the growth rate of the habitat,  $\alpha$ , or the initial size of the habitat,  $H(0)$ , has a positive transitional impact on the number of the species (due to more suitable habitat for the species) and visitors as well. However, an increase in the growth rate of the species,  $\gamma$ , or an increase in the initial size of the bird population,  $S(0)$ , increases only the number of the species

<sup>12</sup> Note that for our initial conditions a period of 10 years is sufficient to reach a very small neighborhood of the bioeconomic equilibrium.

population in transition, but not the size of the habitat (again due to the food chain structure of the ecological system). On the contrary, if  $\beta$ , the conversion rate of  $H$  into habitat suitable for the species is increased, we recognize a negative impact on  $H$  but a slightly positive one on  $U$ . Changes in the remaining parameters point in the same direction as for the bioeconomic equilibrium impacts, and will therefore not be discussed again.

*Table 4: Change in integrated quantities for H, S and U calculated for T = 10*

	Value	$\int H$	$\int S$	$\int U$
$\alpha$	0.4621	+ 0.03%	+ 0.03%	+ 0.03%
$\beta$	0.3843	- 0.01%	+ 0.84%	+ 0.03%
$\gamma$	0.6200	-	+ 0.01%	-
$\omega$	41.630	+ 0.58%	+ 0.47%	+ 0.58%
$\nu$	0.0368	- 0.25%	- 0.2%	+ 0.75%
$\mu$	0.9500	- 0.23%	- 0.18%	+ 0.7%
$\rho$	0.1303	- 0.12%	- 0.1%	- 0.12%
$H(0)$	28.37	+ 0.17%	+ 0.17%	+ 0.17%
$S(0)$	12	-	+ 0.15%	+ 0.01%

As mentioned before, increasing the appreciation of species by visitors (by lowering parameter  $\mu$ ) has a positive impact on  $H$  and  $S$  both in transition and in the bioeconomic equilibrium state. I.e., for smaller values of the parameter  $\mu$ , *ceteris paribus*, the type of the equilibrium changes from a stable node to a stable focus (see Appendix A.2). On the other hand, increasing  $\mu$  towards unity yields a trade-off between current benefits form tourism and current damage of tourism and ‘destabilizes’ the bioeconomic system reflected by a damped oscillating approach to the bioeconomic equilibrium state.<sup>13</sup>

#### 4. Results of the policy scenarios for the Mallnitz Tauern valley

As outlined in Section 2.3, the main interest is to develop strategies for the management of a protected area that allow increasing the number of visitors without causing damage to the ecosystem. We interpret this ‘no damage’ case to guaranteeing that the species population remains constant at the reference equilibrium state, i.e. (7) for  $\psi=\lambda=0$ . Therefore, we investigate combinations of *REG*

<sup>13</sup> Eventually (for large values of  $\mu$ ), this behaviour can lead to persistent oscillation and the occurrence of a limit cycles—however, not for any choice of visitor preference,  $\mu \in [0, 1]$ , given the *Mallnitz Tauern* valley parameter set.

and  $HAB$ —where these combinations (called  $POL$  for policy mix from now on) are set up in such a way that the negative impact of  $REG$  on the equilibrium value of  $S$  is just compensated by  $HAB$ .

#### 4.1 A ‘species neutral’ policy mix

First, we determine all combinations of increasing visitor infrastructure ( $REG$ ) and  $HAB$ itat creation which yield the same equilibrium level for  $S$  as the ‘reference’ equilibrium ( $\hat{S} = 13$ ):

$$F(\psi, \lambda) = \frac{-\beta^{2\mu} + \beta^\mu \sqrt{\beta^{2\mu} + 4\beta^2\nu^2\rho\omega^2}}{2\beta\nu^2\rho\omega} - \frac{2(\beta(1+\lambda))^{1+2\mu}\omega}{(\beta(1+\lambda))^{2\mu} + \sqrt{(\beta(1+\lambda))^{4\mu} + 4(\beta(1+\lambda))^{2(1+\mu)}\nu^2\rho(1+\psi)^2}}$$

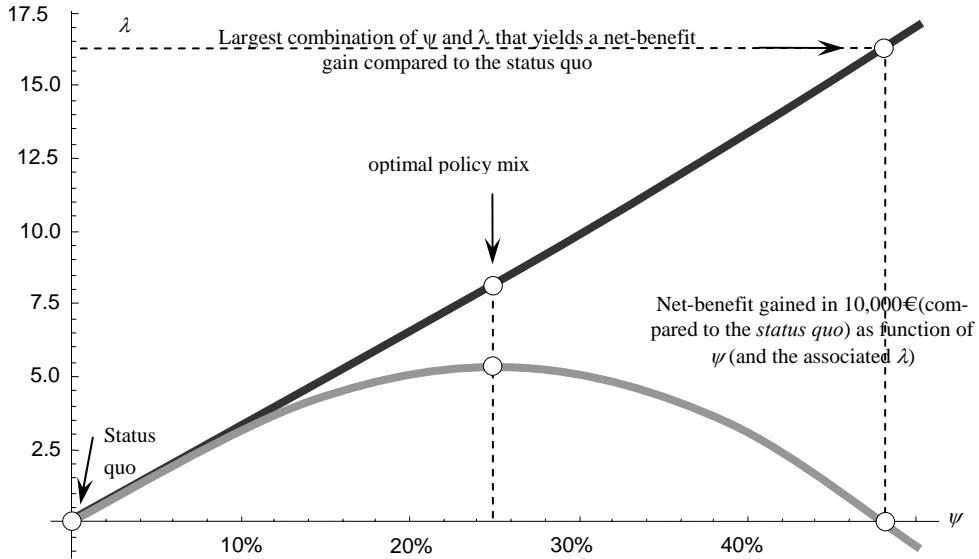
The pairs of combinations  $(\psi, \lambda)$  for which  $F(\psi, \lambda)=0$  are depicted by the (slightly convex) dark line in Figure 2. Thus, the percentage increase in  $\lambda$  that just compensates an additional percent of infrastructure is not constant, but marginally grows with  $\psi$ .

Among all combinations of  $REG$  and  $HAB$  which do not damage the rock partridge population (in its equilibrium state according to Eq. 7), there is only one policy mix which also maximizes the additional net-benefit (defined by Eq. 6):

$$\max NB_{UV+NUV} = \int_{t=0}^T [\kappa U(t)(S(t) - S_0) + \varepsilon(U(t) - U_0) - (\theta\psi^2 + \phi\lambda^2)] e^{-rt} \quad (8)$$

$$\text{subject to } F(\psi, \lambda) = 0.$$

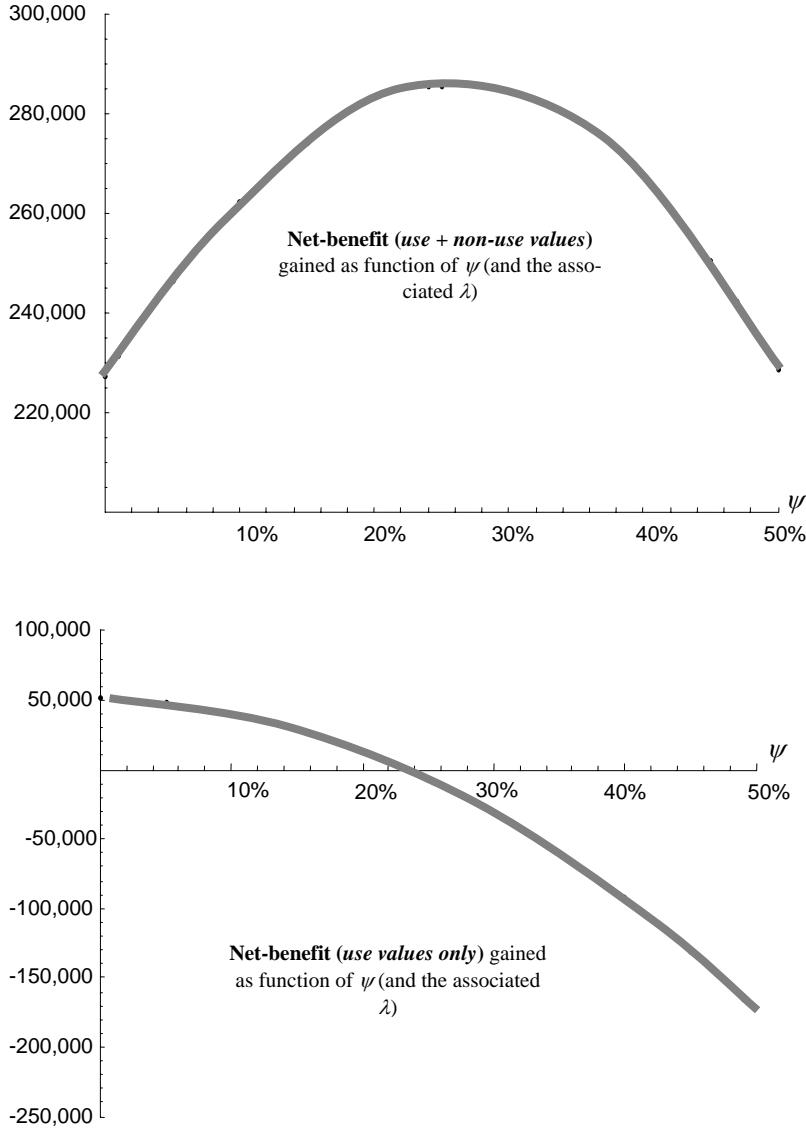
Figure 2: Combination of ecologically neutral policy mixes (black line) and the associated welfare gained (grey line) for the Mallnitz Tauern valley parameter set (Table 1)



For the parameterization for the *Mallnitz Tauern* valley (Table 1 and Table 2) this optimal policy mix allows an increase of visitor infrastructure by  $\psi = 25\%$ . Only combined with a habitat creation policy of  $\lambda = 8.21\%$  this measure accomplishes an equilibrium size of the rock partridge population of 13 breeding pairs —which (by construction) coincides with the ‘reference equilibrium’. The maximum net benefit gained (above the level of €227,139 which yields from maintaining current policy for the next 10 years), however, amounts €53,056. Furthermore, Figure 2 illustrates that the net benefit gained is only positive if the visitor infrastructure does not increase by more than 48% (correlated with a  $\lambda$ -value of 16.32%). Any desired increase in visitor infrastructure going beyond this threshold level reduces welfare (in terms of Eq. 6).

Not astonishingly, the benefit maximizing policy mix depends on the benefit criterion used. Assume, for instance, that the park administration is not able to collect visitors’ willingness to pay for protecting the species under consideration, thus  $\kappa=0$  in (6) and (8). Then, the present value of the stream of net benefits over ten years is a strictly falling function and becomes negative for values of  $\psi$  larger than 24% (see lower graph in Figure 3). Thus, unlike for the case with non-use values (upper graph of Figure 3), where the optimal policy mix is  $\psi=25\%$  and  $\lambda=8.21\%$ , maintaining the current policy, i.e. setting  $\psi=\lambda=0$ , is the optimal policy mix when considering use-values only.

*Figure 3: Net-benefit of different S-neutral policy mixes (combinations of  $\psi$  and  $\lambda$  for which the rock partridge population is kept at the reference level), either considering use and non-use values (upper graph) or use values only (lower graph)*



## 4.2 The trade-offs involved

To illustrate the antagonistic forces of *REG* and *HAB* we split one admissible policy mix, associated with a 10% increase in visitor infrastructure (*REG* +10%) and an extension of the habitat by 3.2% (*HAB* +3.2%), into its components. The results on the equilibrium levels of *H*, *S*, and *U* are reported in Table 5.

Table 5: Effects on bioeconomic equilibrium values, benefits and costs

Policy Scenario	Parameter Values	$\hat{H}$	$\hat{S}$	$\hat{U}$	$BCR$	$\Delta B$	$\Delta NB_{UV+NUV}$	$\Delta NB_{UV}$
No policy ( <i>NoP</i> )	$\psi = 0,$ $\lambda = 0$	33.9	13	1.2	–	1	1	1
Additional visitor infrastructure ( <i>REG</i> )	$\psi = 0.1,$ $\lambda = 0$	–3%	–3.2%	+6.6%	143.1	0.6	0.6	0.21
Habitat creation ( <i>HAB</i> )	$\psi = 0,$ $\lambda = 0.32$	–	+3.2%	+0.2%	65.3	1.5	1.52	0.21
Policy Mix ( <i>POL</i> )	$\psi = 0.1,$ $\lambda = 0.32$	–3%	–	+6.8%	6.3	42.2	1.15	0.18

According to Table 5, the equilibrium number of visitors ( $\hat{U}$ ) is increasing in the *POL*icy mix case and the ‘pure policies’ (relative to no policy case), but strongest in *REG* and *HAB*. The equilibrium size of the species is larger in *HAB* than in *NoP* due to an increase in the size of the habitat. *REG* leads to smaller habitat and smaller species number than *NoP*. The policy mix of both instruments leads to an equal number of species as in *NoP* while the habitat is slightly smaller (due to additional visitor infrastructure). The number of visitors are highest for the policy mix (since visitors are also attracted by the species), and lowest for *HAB*it creation as a single instrument.

Considering benefits and costs of the different policies, all policies are cost-effective (the benefit cost ratios  $BCR$  are considerably larger than one). While for *POL* the change in net benefits compared to *NoP* is positive ( $\Delta NB_{UV+NUV} = 1.15$ ), this policy mix is outperformed by *HAB*it creation ( $\Delta NB_{UV+NUV} = 1.42$ ). If the park administration cannot take hold of donations for species protection and thus only considers expenditures by visitors (i.e., we set  $\kappa=0$ ), the costs of the measures lead to an outranking of all policy options by the no policy case, i.e. *POL* leads to net-benefits (use-values only) of  $\Delta NB_{UV} = 0.18$  only.

Let us now investigate the transition towards the new bioeconomic equilibrium for the different policies. While the time paths for the habitat (and visitors) coincide for *NoP* and *HAB* (and *REG* and *POL*, respectively), the adjustment of the species population is more interesting. *POL* gives the same equilibrium *S* population size as the no-policy case, but during transition *POL* outperforms the no-policy case (see Figure 4). Comparing Figure 5 and Figure 6, the importance of the benefit criterion becomes obvious: Starting with use and non-use values (Figure 5), the slight increase in benefits *NoP* is driven by the increases in *S*, *H* and *U* over time, without causing any costs. For *HAB*, the

benefit increase is mainly driven by the relative increase in  $S$ , leading to a strong increase in the aggregate willingness to pay for species conservation by the visitors. The policy mix ( $POL$ ), despite leading to an increase in  $U$  while  $S$  is kept constant, is only on rank 2, due to the compound costs of the measures. If only use values are taken under consideration (i.e., we set  $\kappa=0$ ), as in Figure 6, the costs tend to drive the results even stronger, such that the no-policy case is to be preferred over all policy options. In this case improving visitor infrastructure ( $REG$ ) is to be preferred to the combined policy  $POL$ , and  $HAB$  is in the final position.

*Figure 4: Time path for species for no policy case (NoP), increase in visitor infrastructure (REG), habitat creation (HAB) and policy mix (POL)*

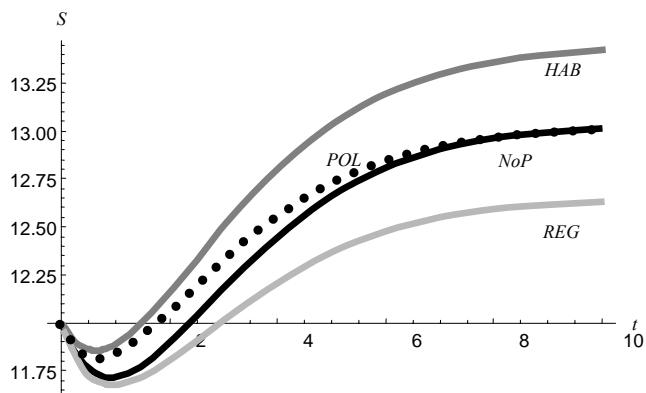


Figure 5: Time path for net benefit for no policy case (NoP), increase in visitor infrastructure (REG), habitat creation (HAB) and policy mix (POL)

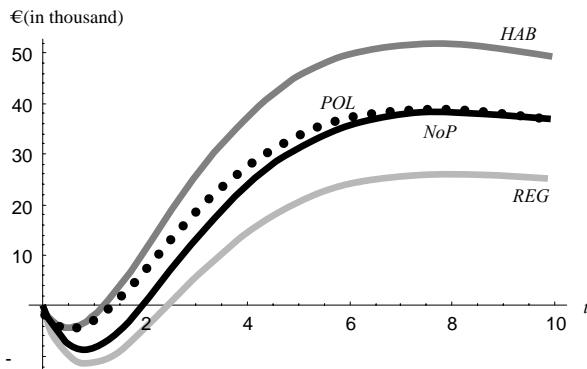
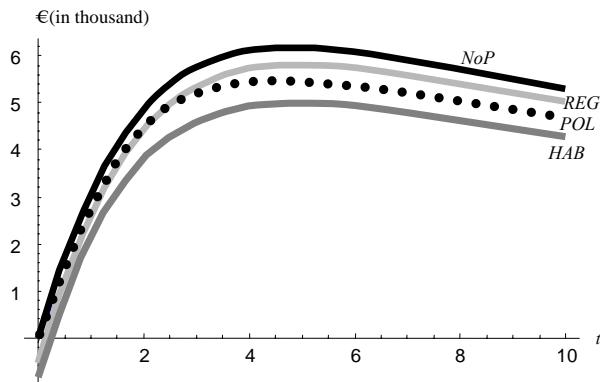


Figure 6: Time path for net benefit (excluding non-use values for S) for no policy case (NoP), increase in visitor infrastructure (REG), habitat creation (HAB) and policy mix (POL)



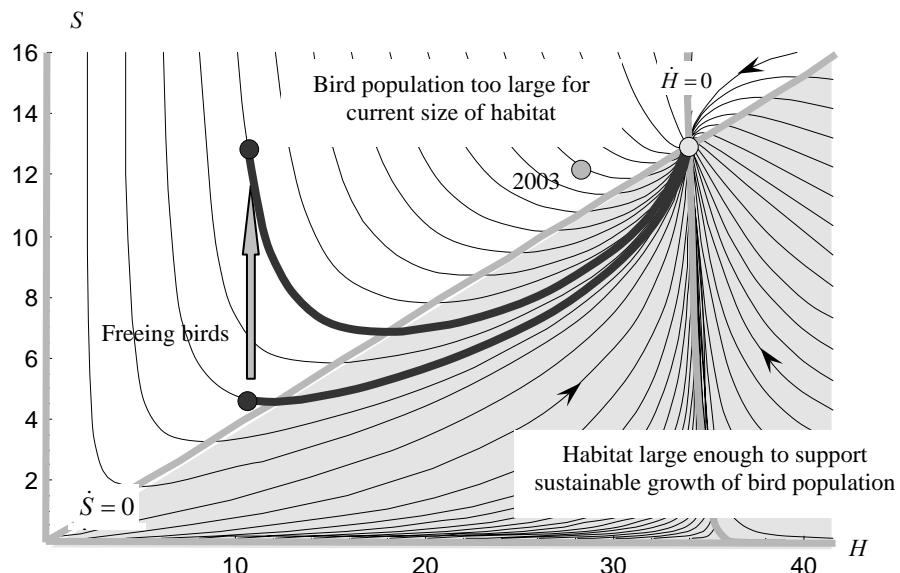
In a nutshell: The well-balanced combination of *REG* and *HAB* serves the decision maker (or social planner) not just as a compromise solution between the local population (via increasing the number of visitors) and the NGOs/future generations (via avoiding a deterioration of the living conditions for the non-charismatic rock partridge, stabilizing the population size at the no-policy equilibrium level) but can create benefits at least as high as in the no-policy case. This is an important result, since the existence and maintenance of a protected area is fundamentally based on the acceptance and the support of the local population.<sup>14</sup> Moreover, this strategy can be regarded not only as *ecologically neutral* but also as superior in the transition towards the equilibrium, since the level of breeding pairs and of total benefits is higher for *POL* than *NoP*. Obviously, this strategy is only welfare maximizing if the park management follows the *welfare maximizing strategy* as indicated in Figure 3 ( $\psi = 0.25$ ,  $\lambda = 0.0821$ ).

<sup>14</sup> Quoting Klaus Eisank, manager in the Hohe Tauern national park: “Nicht von den Steinhühnern leben wir, sondern von den Touristen” (“We do not make our living from rock partridges but from tourists.”)

### 4.3 Other protection measures: species restocking and visitor steering

Finally, let us discuss alternative protection policies such as species restocking or visitor steering: Species restocking can be imagined as improving the birds' birth rate  $\gamma$ . As we see from (9) this policy does not alter the bioeconomic equilibrium, but the transition thereto. Thus, restocking can be essential if the population size is very close to its minimum viable size. Close to the  $\dot{S}=0$  isocline species restocking could, however, be seen as 'waste of resource' since only the transition towards but not the equilibrium itself respond to a change in the birth rate, as depicted in Figure 7 for the base case parameter values (Table 1).<sup>15</sup>

*Figure 7: Effect of freeing if habitat is not large enough: phase diagram for base case parameter values plus 2003 data point*



The situation is a very different one with visitor steering. Visitor steering has the potential of being a very efficient policy yielding ecologically desirable results because it could allow for increasing visitor numbers while holding their negative impact on the ecosystem small. Accordingly, the damage caused to the ecosystem per visitor is addressed and can, hopefully, be influenced in a downward direction. Visitor steering can go in two directions by either directing visitors on particular tracks, and keeping them off sensitive areas (the opposite case of new visitor infrastructure), or

<sup>15</sup> A thought experiment can help to illustrate this matter. The hypothetical case of 5 breeding pairs (marked by a dark circle in Figure 7) could (mis)lead a decision-maker to the idea that freeing would be a good thing. Pushing the population size towards its equilibrium level by adding *ex-situ* reared bird to the area wouldn't really change the situation. In absence of the suitable habitat the birds would migrate or die and the ecological system would approach the bioeconomic equilibrium on its own accord after surpassing the  $\dot{S}$ -isocline.

by informing visitors about their contribution to species endangerment and thereby raising their awareness (like an incentive to change a particular behavior). However, due to the lack of data on the effectiveness of these measures with respect to the recovery rate of the habitat or the species population, we are not able to investigate this case more intensively here.

## 5. Summary and conclusions

The literature regarding land-use, development and conservation often sketches a picture of trade-off between conservation on the one hand, and development and land-use on the other (opportunity cost of conservation). However, conservation and tourism are not necessarily contradictory: Sometimes, they are complements (or at least they can be). Among others, this result is due to the fact that conservation is costly. Ecological management needs resources in terms of research and studying, designing conservation measures and strategies, and realizing the different measures in the field. Conservation budgets are – in times of fiscal austerity – scarce, and many administrations of protected areas aim for different sources of funding besides the public budgets.

Tourism can help in opening up new sources of funding. Improving visitor infrastructure can attract more visitors who are willing to pay for their recreation benefits. Directly, visitors spend money on parking and entry fees, tolls, guided tours and information materials. Indirectly, increased awareness and education leads to higher WTP for species on the basis of non-use values. Such expenditure can be used (and is actually used) for funding of nature conservation measures. The negative impacts of tourism in ecologically sensitive areas are, however, as important. Visitor steering and other measures try to minimize negative impacts on habitats and species. Such measures are not always successful, thus tourism has a two-edged effect. While budget-generating, tourism also brings ecologically negative impacts to a protected area.

In this paper, we discussed these two-edged effects, and tried to value different policy options in a concrete environment, the Tauern Valley in the Hohe Tauern national park, and regarding a concrete species, the rock partridge. It turns out, on the basis of our numerical example, realistic empirical parameters and a GIS model of the region, that there are policies that combine both higher visitor numbers and larger numbers of species. A policy-mix of visitor infrastructure improvements and species protection by extending the (quality and) size of the habitat performs best in terms of combined effects regarding recreation, conservation and funding.

Interestingly, in terms of cost-effectiveness, ‘pure’ policies like conservation or visitor policies, as well as the combined ‘balanced’ approach, are cost-effective. The discounted stream of benefits of these different policies are each larger than their costs. The definition of benefits of rec-

reaction and conservation also determines ranking of the policy options. If visitors acknowledge non-charismatic species, and the park administration can collect (skim off) visitors' willingness to pay for the conservation of this species, policies that include conservation measures are better off. If the revenues are restricted to entrance fees and other direct expenditures etc., conservation policies are less favorable, and tourism projects such as extending visitor infrastructure are better off. The results of the current study reveal – by an actual example of managing a habitat and a species in a concrete environment – that mixed policies of increasing conservation efforts and attracting new visitors to the area can not only increase society's welfare as a whole, but can also increase habitat quality and the number of species living in a certain area.

## 6. Acknowledgements

We would like to thank Brigitte Gebetsroither and Stefan Lieb for their help, suggestions and inputs to the current paper, and the Jubiläumsfonds der Österreichischen Nationalbank (project No. 11216) for financial support.

### Appendix A.1: Local Stability Analysis of the food chain model

Since the initial conditions are always positive ( $H_0, S_0 > 0$ ) and the first quadrant is an invariant set we restrict our analysis to  $\{(H, S) \mid 0 < H \leq \omega, S > 0\}$ . First we derive the equations for the isolines:

$$\dot{H}(t)=0 \Leftrightarrow \alpha \left( 1 - \frac{H(t)}{\omega(1-\rho U(t)^2)} \right) \underbrace{H(t)}_{>0} = 0, \quad (\text{A1})$$

$$\dot{S}(t)=0 \Leftrightarrow \gamma \left( 1 - \frac{S(t)}{\beta(1+\lambda)H(t)} \right) \underbrace{S(t)}_{>0} = 0 \Leftrightarrow S(t) = \beta(1+\lambda)H(t), \quad (\text{A2})$$

where

$$U(t) = \nu(1+\psi)H(t)^\mu S(t)^{1-\mu}. \quad (\text{A3})$$

Thus, the number of visitors for which the size of the bird population remains constant corresponds to the case  $\psi=0$  and can be computed as  $\bar{U}(t) = \nu\beta^{1-\mu}H(t)$  according to Eq. A2.

Moreover, the intersection of the isolines uniquely defines the equilibrium state,

$$\hat{\mathbf{X}} := \begin{pmatrix} \hat{H} \\ \hat{S} \end{pmatrix} = \frac{2\beta^\mu\omega}{\beta^\mu + \sqrt{\beta^{2\mu} + 4\beta^2\nu^2\rho(1+\psi)^2\omega^2}} \begin{pmatrix} 1 \\ \beta(1+\lambda) \end{pmatrix}, \quad (\text{A4})$$

in the relevant part of the positive section of the phase space  $\{(H, S) \mid 0 < H \leq \omega, S > 0\}$ . Using the Jacobian matrix evaluated at the stationary point,

$$\hat{\mathfrak{J}} = \begin{pmatrix} \frac{\alpha(-1-\Theta(-1+2\mu))}{(-1-\Theta)^2\omega} & \frac{\alpha\Theta(\beta(1+\lambda))^{-1}(2-2\mu)}{(-1-\Theta)^2\omega} \\ \frac{\gamma}{\hat{H}} & \frac{\gamma}{\beta\hat{H}(1+\lambda)} \end{pmatrix}, \quad (\text{A5})$$

where  $\Theta = \hat{H}^2(\beta(1+\lambda))^{2-2\mu}\nu^2\rho(1+\psi)^2$

The local stability behavior of the food chain model can be determined in the usual manner by linearization of the system around the equilibrium state (determined by Equation (A4)). The corresponding characteristic polynomial,

$$P(\lambda) = \lambda^2 - \text{tr}\hat{\mathfrak{J}}\lambda + \det\hat{\mathfrak{J}} = 0, \quad (\text{A6})$$

may be solved analytically yielding the spectrum of eigenvalues,

$$\lambda_{1,2} = \frac{\text{tr}\hat{\mathfrak{J}}}{2} \pm \frac{1}{2}\sqrt{\text{tr}\hat{\mathfrak{J}}^2 - 4\det\hat{\mathfrak{J}}}. \quad (\text{A7})$$

Hence, we can describe the stability behavior of the food chain model by linearizing around its equilibrium state.

$$\begin{aligned} \det\hat{\mathfrak{J}} &= \frac{1}{2\omega^2} \left( \alpha\gamma(\beta(1+\lambda))^{-1-4\mu} + (\beta(1+\lambda))^{2\mu} \sqrt{(\beta(1+\lambda))^{4\mu} + 4(\beta(1+\lambda))^{2(1+\mu)}\nu^2\rho(1+\psi)^2\omega^2} + \right. \\ &\quad \left. + 2\beta^2(1+\lambda)^2\nu^2\rho(1+\psi)^2\omega^2 \left( 2(\beta(1+\lambda))^{2\mu} + \sqrt{(\beta(1+\lambda))^{4\mu} + 4(\beta(1+\lambda))^{2(1+\mu)}\nu^2\rho(1+\psi)^2\omega^2} \right) \right) \\ \text{tr}\hat{\mathfrak{J}} &= \frac{1}{2\omega^2} \left( (\beta(1+\lambda))^{-2\mu} \left( -\frac{\gamma(\beta(1+\lambda))^{2\mu} + \sqrt{(\beta(1+\lambda))^{4\mu} + 4(\beta(1+\lambda))^{2(1+\mu)}\nu^2\rho(1+\psi)^2\omega^2}}{\beta(1+\lambda)} \right) - \right. \\ &\quad \left. - \alpha \left( (\beta(1+\lambda))^{2\mu} + 4\beta^2(1+\lambda)^2\mu\nu^2\rho(1+\psi)^2\omega^2 + \sqrt{(\beta(1+\lambda))^{4\mu} + 4(\beta(1+\lambda))^{2(1+\mu)}\nu^2\rho(1+\psi)^2\omega^2} \right) \right) \end{aligned}$$

For the chosen parameter values and  $\lambda \in \{0, 0.25\}$  and  $\psi \in \{0, 1\}$ , we get  $0 < \det\hat{\mathfrak{J}} < 1$  and  $\text{tr}\hat{\mathfrak{J}} < 0$ . Moreover,  $\text{tr}\hat{\mathfrak{J}}^2 - 4\det\hat{\mathfrak{J}} > 0$  and both eigenvalues are real and negative. Thus, we have an improper node which is asymptotically stable.

## Appendix A.2: Parameterization for the rock partridge in the Mallnitz Tauern Valley (Austria)

For the rock partridge population in the *Mallnitz Tauern* valley, the initial state of the ecological system can be parameterized as follows:  $H(0)=28.37$ ,  $S(0)=12$ . According to a GIS model (Behrens et al., 2006), approximately three quarters of the *Tauern valley* can currently be identified as potential habitat suitable for the rock partridge population ( $\omega=41.63 \text{ km}^2$ ) leading to a carrying capacity of the rock partridge of 16 breeding pairs.<sup>16</sup>

The current state of the *Mallnitz Tauern* valley implies a breeding area that is 13% smaller than the pristine carrying capacity, thus  $\rho = 0.1303$  (Behrens et al., 2006). Moreover, in the initial state, the habitat (i.e., its biomass per  $\text{km}^2$ ) is growing slowly, assumingly at a rate that is a reasonably low number for high altitude forest and brush ecosystems of 0.1 (10%), see, e.g., Umweltkontrollbericht (2004). Accordingly, the intrinsic growth rate for  $t=0$  can be estimated as  $\alpha = 0.4621$ . The annual survival rate of the rock partridge population is, on average for male and female,  $\gamma=62\%$  (Hafner, 1994). Since the partridge's carrying capacity is 16 breeding pairs (Behrens et al., 2006), we can set  $\beta H = 16$ . Thus, for  $H=41.63 \text{ km}^2$ , the natural growth rate of the rock partridge is equal to  $\beta \rightarrow 0.3843$ .

According to a visitor count in 2003 (Lehar et al., 2004), the annual number of visitors to the *Mallnitz Tauern valley* is 22,910, which we define as 100% for analytical convenience,  $U(0)=1=100\%$ . Visitor demand is then calibrated as follows. As visitors are highly in favor of the nice landscape (i.e. the habitat) but are quite neutral with respect to the partridge we set  $\mu=0.95$  and we get  $v=0.0368$  for the initial state ( $t=0; H(t)=28.37, S(t)=12, U(0)=1$ ).

The average (hiking) visitor to the *Hohe Tauern* spends €22.87 per day (Lehar et al. 2004). Most of the costs are private costs which cannot be devoted to financing visitor infrastructure, such as meals and beverages, fuel, and cable car tickets. However, some spending categories can be related to visitor infrastructure maintained by the park management: parking fees, guides and hiking tours, and entrance fees, leaflets, souvenirs issued by the park management, yielding infrastructure expenditures per visitor of  $\varepsilon = 0.00180$  (in 1,000 Euros).

---

<sup>16</sup> For a habitat suitability analysis by means of a GIS model, see Behrens et al., 2006. According to slope steepness, vegetation (brushwood and small bushes are the suitable retreat area for the partridge), and human influences from existing trekking trails and skiing tour routes, the suitable habitat and maximum population size were estimated. The same model was applied to different protection measures (e.g. seasonal closings) and visitor infrastructure (new trails and outdoor activities) to estimate the impact on breeding area, overall habitat and species numbers.

From a contingent valuation survey ( $n=211$ ) among the visitors to the *Hohe Tauern* national park the mean willingness to pay for an increase in the rock partridge population from 12 to 16 breeding pairs in the *Mallnitz Tauern valley* was investigated (for details, see Behrens et al., 2006). The mean WTP per breeding pair can be estimated to be € 1.72 (lump sum, not annual payment), or  $\kappa=0.00172$ .

According to Getzner *et al.* (2002) the cost of setting up an additional hiking trail is of the order of €1,000-2,000 per kilometer. Since this is a very conservative estimation, we take the larger value and for the annual fixed cost per km. Annual maintenance cost (variable cost) amounts to approximately 5% of investment cost, i.e., €75-100 per km (Getzner *et al.*, 2002). Then, the annual cost of increasing the trail network to 41.896 km (associated with  $U=1.5$ ) can be calculated as  $C_1(\psi)=41.896(2,000/T+100)=12,568.80$  yielding  $\psi=1.0388\text{€}$  (for  $T=10$ ) and thus  $\theta \approx 11.64743$ .

The cost of habitat creation can be estimated in a straight forward way. An increase in the breeding area by 1 km<sup>2</sup> increases the rock partridge population by 1.1 breeding pairs (Behrens et al., 2006). In particular, we calculate the size of the parameter  $\lambda$  for our initial conditions ( $t=0$ ,  $H(0)=28.37$  and  $S(0)=12$ ) and for  $\beta=0.3843$  and  $\gamma=0.62$ , as  $\lambda=0.29162$ . According to Getzner *et al.* (2002) habitat maintenance cost is €40,000-70,000 per km<sup>2</sup> and per year, and as a first approximation we take the lower value for the variable costs. Moreover, per additional km<sup>2</sup> of habitat start-up and one-time measures of €90,000 p.a. are necessary. Proceeding analogously as for the estimation of the cost parameters for new visitor infrastructure, the cost parameter can thus be calibrated as  $\phi \approx 633.89$ .

## References

- Ando, A., Camm, J., Polasky, S., Solow A. (1998). Species distributions, land values, and efficient conservation. *Science* 279: 2126-2128.
- Ando, A., Getzner, M. (2005). The roles of ownership, ecology, and economics in public wetland-conservation decisions. *Ecological Economics* 58(2): 287-303.
- Behrens, D., Friedl, B., Gebetsroither, B., Getzner, M., Lieb, S. (2006). Optimal dynamic nature conservation strategies. Final report to the Jubiläumsfonds der Oesterreichischen Nationalbank (Austrian Central Bank), project No. 11216, Klagenfurt/Graz.

- BirdLife International (2004). Birds in Europe: population estimates, trends and conservation status. *Birdlife Conservation Series* 12, Birdlife International.
- BirdLife International (2005). Species fact sheet: *Alectoris graeca*. Downloaded from <http://www.birdlife.org> on 9/12/2005.
- Bulte, E. van Kooten, G.C. (2002). Downward sloping demand for environmental amenities and international compensation: elephant conservation and strategic culling. *Agricultural Economics* 27: 15-22.
- Conrad, J.M. (1999). *Resource Economics*. Cambridge: Cambridge University Press.
- Conrad, J.M. and Salas, G. (1993): Economic Strategies for Coevolution: Timber and Butterflies in Mexico. *Land Economics* 69(4), 404-15.
- Costello, C., Polasky, S. (2004). Dynamic reserve site selection. *Resource and Energy Economics* 26: 157-174.
- Dawson, D. and Shogren, J.F. (2001). An update on Priorities and Expenditures under the Endangered Species Act. *Land Economics* 77(4): 527-532.
- Duffus, D.A., Dearden, P. (1990). Non-consumptive wildlife-oriented recreation: a conceptual framework. *Biological Conservation* 53: 213-231.
- EUROPARC and IUCN (2000). Richtlinien für Managementkategorien von Schutzgebieten – Interpretation und Anwendung der Managementkategorien in Europa. Europarc and WCPA (World Commission on Protected Areas), Gland (Switzerland) / Grafenau (Germany).
- Frey, H. (1999). Estimation of the costs for captive bred Bearded Vultures within the framework of the European Bearded Vulture project. Bearded Vulture. Reintroduction into the Alps. Annual Report. 1998, 75-77.
- Friedl, B. and Behrens, D.A. (2006). Optimal Balancing of Recreation and Wildlife Conservation: A Case of the Golden Eagle, In: A. Kontoleon and T. Swanson (eds.), *Frontiers of Biodiversity Economics*, Cambridge: Cambridge University Press.
- Getzner, M., Jost, S., Jungmeier, M. (2002). Naturschutz und Regionalwirtschaft: Regionalwirtschaftliche Auswirkungen von Natura 2000-Gebieten in Österreich. Peter Lang: Frankfurt am Main.
- Hafner, F. (1994). Das Steinhuhn in Kärnten. Ökologie, Verhalten und Lebensraum. Carinthia II Special Issue No. 52, Naturwissenschaftlicher Verein für Kärnten: Klagenfurt, Austria.
- Hoekstra, J. and van den Bergh, J.C.J.M. (2005). Harvesting and Conservation in a Predator-Prey System. *Journal of Economic Dynamics and Control* 29(6): 1097-1120.

- ITR (2001). Nationalparks und Tourismus in Österreich 2001. Institut für touristische Raumplanung (ITR), Vienna.
- Lehar, G., Hausberger, K., Fuchs, L. (2004). Besucherzählung, Wertschöpfungs- und Motiverhebung im Nationalpark Hohe Tauern und im Naturpark Rieserferner-Ahrn. Institut für Verkehr und Tourismus – Innsbruck, Studie i.A. des Nationalpark Hohe Tauern.
- Metrick, A., Weitzman, M.L. (1998). Conflicts and choice in biodiversity protection. *Journal of Economic Perspectives* 12(3): 21-34.
- Pachlatko, T. (1991). Costs of the international project 1980 –1990. *Gypaetus barbatus* 13: 42.
- Parks, P., Kramer, R., Heimlich, R. (1995). Simulating cost-effective wetlands reserves: A comparison of positive and normative approaches. *Natural Resource Modeling* 9: 81-96.
- Polasky, S., Camm, J., Garber-Yonts, B. (2001). Selecting biological reserves cost-effectively: An application to terrestrial vertebrate conservation in Oregon. *Land Economics* 77: 68-78.
- Robin, K., Müller, J.P., Pachlatko, T., Buchli, C. (2004). Das Projekt zur Wiederansiedlung des Bartgeiers in den Alpen ist 25-jährig: Ein Überblick. *Der Ornithologische Beobachter* 101(1): 1-18.
- Skonhoft, A. (2005). The costs and benefits of animal predation: An analysis of Scandinavian wolf-recolonization. *Ecological Economics* (forthcoming).
- Umweltkontrollbericht (2004). Seventh state of the environment report. Umweltbundesamt, Vienna.
- Wätzold, F., Schwerdtner, K. (2005). Why be wasteful when preserving a valuable resource? A review article on the cost-effectiveness of European biodiversity conservation policy. *Biological Conservation* 123: 327-338.