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Abstract

The EU Habitats Directive provides in Annexes II and IV a list of species needing to be conserved. Member States have implemented a variety of conservation measures in response to this obligation. These measures include the rejection, modification or delay of land development plans, payments for landowners to perform conservation measures and management actions such as breeding programmes. The costs of the various conservation measures are not always apparent. There may be an underestimation of the resulting costs when land development plans are altered, because there is no visible flow of financial resources. Such a biased perception may result in selecting conservation measures with high but less visible costs, whereas conservation measures with low but more visible costs are neglected. The purpose of this paper is to contribute to avoiding a biased selection of conservation measures by presenting a framework which captures a broad variety of costs relevant to the conservation of species protected by the Habitats Directive. We also demonstrate the relevance of a biased selection of conservation measures by using the framework to empirically estimate the costs of protecting the common hamster (*Cricetus cricetus*) in the region of Mannheim, Germany. We find that the less visible costs of changes in development plans are significantly higher than the more visible costs of payments to landowners and management actions. This result suggests that measures with visible costs should be given more attention in the future.

Keywords: Common hamster; Cost assessment; Cost-effectiveness; EU Habitats Directive; Land use; Spatial planning; Species conservation

Introduction

The Habitats Directive (EG 92/43/EEC) is a key European law that requires governments to conserve endangered species, particularly those species listed in Annex II and IV of the Directive. A variety of conservation measures has been implemented for this purpose, ranging from the rejection or modification of land development plans to management actions (e.g. BFN, 2005). Alternatively, development plans may include measures to compensate for the negative effects on endangered species such as breeding programmes, monitoring measures, ecological upgrading of natural areas or payments to landowners who manage their land in a way that is beneficial to the species (e.g. Palerm, 2006). The modification of development plans or the development of adequate compensation measures also often leads to a delay of development projects.

The extent of the cost of these various conservation measures is not always apparent, particularly when land development plans are rejected, modified or delayed. In such cases, there is no visible flow of financial resources which may lead to an underestimation of conservation costs. In contrast, costs which are accompanied by a direct flow of financial resources, such as payments to landowners for species protection measures are more visible and may be given more attention. Such a biased perception may result in policy makers and conservation managers selecting conservation measures with high but less visible costs, whereas conservation measures with low but more visible costs are neglected. If high cost and low cost measures have a similar impact, then the criterion of cost-effectiveness is violated, which implies that a policy shift from high cost to low cost measures can generate a higher level of species conservation for given costs (see e.g. Birner and Wittmer (2004) and Wätzold and Schwerdtner (2005) for detailed definitions of cost-effectiveness). To avoid a biased selection, next to estimating the effects of various conservation measures on species a proper estimation of their costs is required (Murdoch et al., in press).

The first purpose of this paper is to contribute to avoiding the selection bias by providing a framework which captures a broad variety of costs relevant to the conservation of species protected by the Habitats Directive. The application of this framework as a decision-support would ensure that all conservation costs are given adequate attention. The second purpose of the paper is to demonstrate the relevance of the biased selection problem by applying the framework to empirically estimate the costs of protecting the common hamster (*Cricetus cricetus*, a species listed in Annex IV of the Habitats Directive) in the region of Mannheim, Germany. We find that the 'less visible' costs of changes in development plans are significantly higher than the 'more visible' costs of management measures. Ecological literature suggests that the less expensive management actions, which up to now have been carried out to only a small extent, are at least equally important to hamster conservation as the more expensive measures (e.g., Ulbrich and Kayser, 2004). Our research is motivated by implementing policies in the context of the EU Habitats Directive, but the analysis is relevant to other endangered species whose conservation may be achieved through a similar range of measures.

Our work is related to research on developing frameworks to integrate different types of costs into the design of conservation measures (e.g. Birner and Wittmer, 2004; Wätzold and Schwerdtner, 2005; Drechsler et al., 2006; Naidoo et al., 2006). In contrast to other studies, however, it considers in detail the costs related to the rejection, modification and delay of development plans. Furthermore, our work is related to the empirical assessment of conservation costs. We take into account a large variety of conservation measures, whereas the focus of other empirical studies is usually on one aspect of conservation cost (regional differences in conservation spending, James et al., 1999; Balmford et al., 2003; potential savings on management costs through preventing ecosystem degradation, Wilcove and Chen, 1998; Chen, 2001; Wamelink et al., 2005; costs of agri-environmental measures targeted at biodiversity conservation, Hampicke and Roth, 2000; MacMillan et al., 2004; Holzkämper and Seppelt, 2007; Drechsler et al., 2007; opportunity costs of reserves sites, Rubin et al., 1991; Chomitz et al., 2005; Naidoo and Adamowicz, 2006).

A framework for assessing conservation costs

Selected aspects of economic cost assessment

We start this section with a brief introduction to economic cost assessment focusing on a few selected aspects relevant for determining costs of conserving species protected by the Habitats Directive. A more detailed treatment of cost estimation methods applicable in the context of environmental and resource protection can be found in, e.g., ADB (1997) and USDA (2001).

Economists think of costs in terms of opportunity costs. Opportunity costs arise because the use of a scarce resource such as land, labour and public or private funds for one specific opportunity precludes the use of this resource for other opportunities. In such a setting with choices, opportunity costs of a decision for one opportunity are defined as the foregone benefits of not being able to choose the most highly valued of the other opportunities (see e.g. Buchanan, 1998). For the purpose of illustration, assume that the use of a piece of land for biodiversity conservation precludes its use as a fun park, an industrial area or a housing estate. Suppose that among the alternatives that were not chosen an industrial area is given the highest priority. Then the opportunity costs of the decision to use the land for biodiversity conservation are the foregone benefits of not being able to use this land as an industrial area.

In most studies, market prices are used as an indicator for assessing opportunity costs. Opportunity costs and market prices are closely linked in a functioning market because of the way in which a market economy sets prices. Consider as an example a piece of land which might be used either for biodiversity conservation or economic development. The opportunity costs of using the land for conservation are high if economic development generates a substantial amount of income. Market prices would reflect these high opportunity costs because developers might be willing to pay a high price for the land due to the good income prospects. Market systems, however, do not always function well. For example, external costs that arise, e.g., if consumption or production leads to pollution, are not reflected by market prices. When using market prices to assess opportunity costs it needs to be borne in mind that if market failures exist, market prices are a somewhat distorted indicator for opportunity costs (e.g., Willis et al., 1997).

One important aspect of cost estimation concerns the timing of costs. Costs for conservation measures often occur at various points in time. In such circumstances, costs cannot simply be added because 1€ available one year from now is not as good as 1€ available today. A straightforward explanation is that 1€ available now could be invested to earn interest and would be worth more than 1€ in one year. If the interest rate is δ then 1€ invested for t years will become $(1+\delta)^t$€ in t years. Therefore, the amount of money that would have to be deposited now in order to grow to 1€ in t years in the future is $(1+\delta)^{-t}$€. This is referred to as the discounted or present value of 1€ available t years in the future. Economists usually refer to δ as the discount rate, rather than the interest rate. In long-term studies such as the Stern Review, the discount rate is a complex and much debated issue (e.g. Dasgupta, 2006; Nordhaus, 2007). We do not wish to enter into the technicalities of the discount rate here, but refer to a clear exposition provided by Heal (2007).

A framework for estimating different conservation cost types

As pointed out in the introduction a variety of conservation measures may be implemented in the context of the Habitats Directive. Based on these measures and the various types of opportunity costs they incur we differentiate between

- Costs of rejecting, modifying and delaying development projects
- Costs of conservation management
- Costs of payments to landowners for species protection measures

Costs of rejecting, modifying and delaying development projects

Developing a certain area for industrial, housing, infrastructural or recreational purposes may negatively impact the population of an endangered species. For reasons of conservation, development projects may be delayed, modified or, less frequently, completely rejected. In explaining the opportunity costs that arise from these impediments we will present some simple mathematical formulae which we will also use to estimate opportunity costs in the case study.

Consider an area where an economic project is planned that consists of building a production facility for a good. The benefit from producing one unit of the good in period t equals the difference between its production costs c_t and market price p_t. Suppose now that without the conservation project, quantity q_t^P would have been produced in each period, providing a total benefit of B_P. If the project is completely rejected and no economic activity is possible in the area, the opportunity costs of rejecting the project C_O equal the foregone benefits of production $-B_P$. Suppose now that the project is allowed, but conservation restrictions require changes to the development plan. Therefore, it is only possible to produce $q_t^R < q_t^P$, implying that the benefit $B_R<B_P$ can be realised. This leads to opportunity costs C_O^R in terms of foregone benefits $B_R - B_P$. Taking into account the economic life span of the project T and the discount rate δ we can now write the opportunity costs of modifying a project as

$$C_O^R = B_R - B_P = \int_{t=0}^{T} (p_t - c_t) q_t^R e^{-\delta t} dt - \int_{t=0}^{T} (p_t - c_t) q_t^P e^{-\delta t} dt = \int_{t=0}^{T} (p_t - c_t)\left(q_t^R - q_t^P\right) e^{-\delta t} dt \qquad (1a)$$

To calculate the opportunity costs C_O^D of delaying a project by *n* periods the benefits of a delayed project B_D have to be compared with the benefits of a project that starts on time B_P.

$$\begin{aligned} C_O^D = B_D - B_P &= \int_{t=n}^{T+n} (p_t - c_t) q_t^P e^{-\delta t} dt - \int_{t=0}^{T} (p_t - c_t) q_t^P e^{-\delta t} dt \\ &= -\int_{t=0}^{n} (p_t - c_t) q_t^P e^{-\delta t} dt + \int_{t=T}^{T+n} (p_t - c_t) q_t^P e^{-\delta t} dt \end{aligned} \quad (1b)$$

One insight from spatial economics is that in a functioning market, the price of a parcel of land allocated to a particular type of land use equals the sum of the discounted periodical benefits (e.g., Alonso, 1964). This implies that market prices can be used to approximate B_P, B_R and B_D. Whether market prices or the formulae given above are used, is largely a matter of data availability. Note that if market prices are used, then these prices implicitly reflect the discount rate and the time horizon used in any given type of land use. These parameters may not always be comparable with discount rates and time horizons relevant to other conservation cost types. In order to make the discounted values of the various cost categories comparable to each other, some recalculations may be needed.

Costs of conservation management

Costs of management are those associated with establishing and implementing a conservation management programme. They comprise the material, personnel and overhead costs for all conservation measures. Examples of management costs are costs for breeding programmes, for building bridges or tunnels to allow species to cross roads, and for fences to protect a reserve. Other examples are costs for monitoring species populations and the effects of conservation measures. Costs may also arise for coordinating the various activities. Data to estimate these costs based on market prices for goods and labour should be rather easily accessible.

Costs of payments to landowners for species protection measures

Payments are often made to landowners to compensate them for applying less intensive production techniques which are good for endangered species but lead to a loss of income. Such payments are most frequently applied in agriculture, e.g., for using less fertilisers and pesticides or for applying a species-friendly mowing regime (e.g. Kleijn and Sutherland, 2003). They may also be used, however, in other areas where species conservation depends on land use patterns, e.g. in forestry. The calculation of the foregone benefits of the conservation measures, i.e. their opportunity costs, is often straightforward. The reason is that calculation techniques such as gross margin calculations for estimating profit losses in the field of agriculture are readily available. Participation in payment schemes is mostly voluntary and land owners are unlikely to participate in schemes unless the compensation offsets their foregone profits. The outlays for compensations are therefore usually a good approximation of the opportunity costs of the protection measures. If these costs differ among landowners and payments are uniform, payments may somewhat overestimate opportunity costs. Hence, payments indicate an upper boundary on the opportunity costs of the conservation measure.

Case study: The common hamster in Baden-Württemberg (Germany)

Importance and situation of the common hamster in the case study region

The common or black-bellied hamster (*Cricetus cricetus*) used to be a numerous species that occurred throughout Western and Eastern Europe (Weinhold and Kayser, 2006). Around 1960-1970, population numbers started to dwindle due to excessive trapping, use of rodenticides, and intensification of agricultural practice (e.g., Neumann et al., 2004; Ulbrich and Kayser, 2004). The existence of the
common hamster is now severely threatened, and as of 1992, the species has been listed as an Annex IV species in the EU Habitats Directive. This means that the common hamster is classified as 'strictly protected' and requires protective measures besides securing enough habitat. These measures include monitoring and a moratorium on hunting and destruction of habitat.

The Western-most populations of the common hamster are in Belgium, The Netherlands, and France, where the hamster has suffered severe population breakdowns and genetic impoverishment (Neumann et al., 2004). The German hamster populations are important contributors to the stock of common hamsters in Western Europe, because of their role as bridges to hamster populations in Eastern Europe and Asia (Neumann et al., 2005). In Germany, the regions that contain populations of the common hamster are Baden-Württemberg, Bavaria, Lower Saxony, Hesse, North Rhine-Westphalia and Saxony-Anhalt. Protection of the common hamster is now a serious consideration in spatial planning in these regions.

Figure 1. Spatial distribution of the common hamster in Baden-Württemberg in 1936 (grey areas) and 1995 (circled). Source: http://www.institut-faunistik.net/feldhamster/verbreitung.html

For Baden-Württemberg Vogel (1936) records the hamster to be present in the four grey areas shown in Figure 1. At this time, the hamster population in the Southern-most habitat was relatively small. The largest habitat area was along the river Neckar from Stuttgart to Heilbronn. The eastern-most of the two smaller habitat areas in the north acted as a bridge to another hamster population. In 1995, none of these habitat areas contained hamsters (Weinhold and Kayser, 2006). The only habitat in Baden-Württemberg currently populated by the common hamster is the North-Western area, located near the city of Mannheim (Rhein-Neckar district).[i]

For several years, the city of Mannheim has been preparing plans to develop several large commercial and residential areas located in or near areas that are crucial to the region's hamster population (see Table 1). As a consequence the regional office of the BUND, a large non-governmental environmental organisation, lodged an official complaint with the EU.[ii] The development plans have finally been put into effect, however, although in a modified version and with significant compensation measures.

Table 1. Description of land development projects in the region of Mannheim with impact on hamster habitat

Development project	*Project description*
SAP Arena	44.2 ha of sporting, commercial and parking facilities. Construction of light rail tracks to the SAP Arena.
Sport and fair area	10 ha sport facilities and at most 0.5 ha of additional parking space; Complement to SAP Arena.
IKEA	34.6 ha for IKEA branch.
Sandhofen	Residential area of 6,4ha, with possibility of further 17,5 ha.
Hochstätt	Residential area of 12 ha.

Measures for hamster conservation in Mannheim

We have chosen the region of Mannheim as our case study area, because a relatively wide selection of conservation measures has been implemented explicitly for the protection of the common hamster (SM, 2005). Furthermore, conservation measures are substantial but not as extreme as they have been in some other cases. In North Rhine-Westphalia, for instance, the hamster has been linked to the delay and obstruction of two very large projects. Choosing such a case study where very large investments are involved would present an extreme rather than a typical case. It is also controversial that hamster conservation was the only reason for the delay and rejection of the two projects.[iii] The measures in Mannheim also have the advantage that they seem to have a marginal impact on the respective markets. If we were to consider non-marginal changes, such as would result from changes to large-scale development projects, we would have to take into account in our cost assessment that non-marginal changes in the supply of a good have an effect on market conditions. This would mean a change in market prices and market equilibrium (see e.g. Hanley and Spash, 1993 of how such effects would influence a cost assessment). The marginal changes in the Mannheim region imply that market conditions remain stable and that we can use current market prices.

We interviewed local experts to find out the various measures implemented for hamster conservation in the region of Mannheim and analysed local media, including publicly available documents from city council meetings. The conservation measures that have been implemented are summarised in Table 2, which presents a variety of measures that are to a large extent part of the 'Species Protection Programme Common Hamster' (SPPCH). The SPPCH started in 2001 and is scheduled to run for ten years, after which a programme evaluation will determine whether the programme will be continued.

Table 2. Measures to protect the common hamster in the region of Mannheim

	Compensation payments	*Conservation management*	*Rejection, modification and delay of development projects*
Species protection programme common hamster (SPPCH)	Voluntary agreements for 18 ha of agricultural land	Mapping, monitoring, breeding programme	-
Development project			
SAP Arena	-	1 km fence	Parking lot reduced by 7 ha; multi-storey garage instead of parking lot
Sport and fair area	-	-	-
IKEA	-	1 km fence	450 ha of mostly agricultural land appointed nature reserve
Sandhofen	-	1 km fence	Building of 6.4 ha delayed by one year; possible extension rejected
Hochstätt	-	-	Residential area reduced by 10 ha

The SPPCH started with the mapping of the hamster distribution in the region. The resulting maps of the distribution of hamster populations have formed the basis for other measures aimed at compensating for the negative effects of the development projects on hamster habitat. Monitoring occurs at regular intervals, the frequency of which is scheduled to decrease over time. During the construction of development projects, moreover, animal fences have been built to keep hamsters from wandering into the intended development locations. Currently, the SPPCH also includes population support measures that consist of importing hamster specimens from Eastern-European countries and a breeding programme. This programme may be stopped before the ten-year time span of the SPPCH if monitoring indicates that the hamster population is stable and viable.

The SPPCH also comprises the implementation of compensation payments to farmers for species protection measures. In 2006, around 24 hectares of agricultural area are contracted (FN, 2006). Each five-year contract obliges the farmer to use less intensive methods of farming, namely: delaying the ploughing of harvest remains until the middle of October; leaving some remains of the harvest on the field; reducing the use of herbicides and insecticides; ploughing no deeper than 25 cm; not harvesting strips of 5 m width on every hectare; and growing perennial plants, such as alfalfa. The compensation scheme does not account for spatial heterogeneity of costs and habitat quality, so all contracted farmers receive the same level of financial compensation.

The consequences of hamster protection for development projects have been diverse, both in extent and content. In the case of the SAP-Arena, 7 hectares of one of the four public parking spaces were stricken from the design. This parking facility has been built as a three-storey garage to compensate for the consequent loss of parking spaces. In terms of building costs, the net result of this change seems to have been roughly zero: the extra costs of the garage are compensated by lower costs of land acquisition. Nonetheless, a garage may have higher maintenance costs than a parking lot (e.g. DMT, 2002) and hence cause lower yearly profits.

The building of the IKEA branch led to the legal protection of the 'Strassenheimer Hof`, an area of 450 hectares of mostly agricultural and some residential area. This protected area will serve as habitat for hamsters from the breeding programme as well as for hamsters that may have to be moved to allow development to go ahead. Agricultural activities are permitted to continue in the protected area, but residential development is no longer possible (SM, 2005a; 2006).

The proposed spatial extents of the residential projects Sandhofen and Hochstätt have been reduced by 17.5 and 10 hectares, respectively (SM, 2006). In the case of Hochstätt, this reduction is based on the 'small expansion' variant. A 'large expansion' plan also existed in earlier spatial planning documents, but it had already been rejected in light of new predictions of the human population in Mannheim that removed the need for large-scale development. Furthermore, the presence of the hamster has been linked to a one-year delay of the Sandhofen project which has an area of 6.4 hectares (SM, 2004). There have been no housing projects in other areas to compensate for the restrictions in Sandhofen and Hochstätt.

Costs of hamster conservation

Data uncertainty and estimation scenarios

The cost data were gathered primarily from local experts, media, and public documents. For some data, we had to expand our search to the non-local literature to find indications of the required estimation parameters. We acknowledge that there is a significant degree of uncertainty in some parts of our estimation. We address this uncertainty by providing a low-cost and a high-cost estimation which represent a likely lower and upper boundary of our cost estimations.

For a large part, the uncertainty concerns the data from the parking company, which was unwilling to provide sensitive data on operating costs and profits. As an alternative source, we used published data from an international parking company on their average annual profit rates per parking space over the period 2002-2005, which is €287[iv]. This data was used to estimate the profit loss that arises because the parking company in Mannheim built 1,110 parking spaces less than planned. To take data uncertainty into account, we estimate that in the high cost scenario the profit of the parking company in Mannheim is 25% higher and in the low cost scenario 25% lower than €287. Furthermore, profit losses may have arisen from having had to build a parking garage rather than a parking lot. This assumption is based on a study into the costs and benefits of parking spaces by the Dutch ministry of transport (DMT, 2002). This study mentions that operating costs of parking garages are

€1,030 per year per parking space higher than for parking lots. Considering that the profit of the international parking company is €287 per parking space, this cost difference seems very high. Therefore, we make the more conservative estimate that the annual profit per parking space is 10% lower for a parking garage than for a parking lot.

Additional uncertainty is related to the economic losses that arise from the legal protection of the Strassenheimer Hof, since we were unable to uncover whether any small-scale development had actually been planned. Given that the administration of Mannheim did not plan any large-scale development, it seems unlikely that the full 450 hectare or even a significant part would have been developed. Since there is, however, some residential development in this area, proposals for marginal increases in residential area may have been considered. We assume that in the low-cost scenario no development was planned, and in the high-cost scenario that two hectares may have been developed into housing.

Table 3. Summary of parameter settings for the scenarios

Source of uncertainty	*Low-cost scenario*	*High-cost scenario*
Profit loss parking garage	Profit margin 10% lower	Profit margin 25% lower
Foregone development at Strassenheimer Hof	0 ha developed	2 ha developed
Discount rate	- 7% if annual data are used - 2% if land market prices are used	- 2% if annual data are used - 7% if land market prices are used

Different types of costs arise at different points in time. We calculate aggregated discounted costs for a period of ten years to make the various costs comparable. These ten years reflect the period from 2001 until 2010 for which the 'Species Protection Programme Common Hamster' is certain to be in place. Considering uncertainty about the discount rate, we set it in the high-cost estimation at a real rate of 2%, and in the low-cost estimation at 7%. The reverse holds when we recalculate land market prices to make time horizons and discount rates comparable over different cost types. As Appendix I shows, if a high discount rate is used, then the periodical payments contributing to the market price of land will be low and hence their net present value will also be low. As for the time horizon considered in the land market (T in equation 1b), we use the depreciation period for housing as determined by German tax laws, which is 50 years. Table 3 contains a summary of the various parameter settings for the low-cost and high-cost scenarios

Costs of payments to landowners for species protection measures

The opportunity costs of income loss due to hamster conservation measures are relatively easily calculated. In 2006, 24 hectares are contracted which we assume to be the average area contracted over the period of the SPPCH. The compensation that landowners receive annually is €1,200 per hectare, which makes a total expense of €28,800 per year.[v] All programmes are scheduled to run for ten years, after which the programme is possibly terminated. The net present value of the opportunity costs of income loss, rounded off to the nearest €1, amounts to

$$\int_0^9 €28,800e^{-0.07t}dt = €214,453 \quad (2a)$$

$$\int_0^9 €28,800e^{-0.02t}dt = €263,647 \quad (2b)$$

Costs of management

The city of Mannheim spends yearly approximately €120,000 for hamster conservation. This number includes the expenses for compensation schemes, so we estimate the annual management costs at €91,200. This number reflects the (personnel and material) costs of the monitoring efforts, the population support programme and the overall management costs. Additional to this are the costs of the three animal fences, which each cost €30,000. These costs were incurred only once at the start of the SPPCH. Again, we consider the yearly costs for a ten-year period only at the previously used discount rates:

$$€90,000 + \int_0^9 €91,200e^{-0.02t}dt = €924,881 \quad (3a)$$

$$€90,000 + \int_0^9 €91,200e^{-0.07t}dt = €769,101 \quad (3b)$$

Costs of rejecting, modifying and delaying development projects

As explained above, estimating the opportunity costs of development restrictions may require detailed calculations. We use equation (1a) to estimate costs for restrictions on parking facilities. In the case of the SAP-Arena parking garage, the original plans were to develop 3,110 parking spaces, whereas 2,000 are now available. Hence, the restrictions led to a loss of profits from 1,110 parking spaces. Furthermore, the restrictions led to lower profits from the remaining 2,000 parking spaces because a parking garage had to be built instead of a parking lot. In the low-cost and high-cost scenarios, respectively, profit per parking space in a garage is €215 and €359, and additionally profit from a parking space in a parking lot compared to a garage would have been €22 and €36 higher. Total foregone profits then are

$$\int_0^9 (€215 * 1100 + €22 * 2000)e^{-0.07t}dt = €2,081,236 \quad (4a)$$

$$\int_0^9 (€359 * 1100 + €36 * 2000)e^{-0.02t}dt = €4,272,358 \quad (4b)$$

Calculating the opportunity costs of building regulations for the other affected development projects is a matter of comparing agricultural land use with the alternative land use which was planned to be residential area. According to the statistical office of the ministry of agriculture in Baden-Württemberg, agricultural land prices amounted to €19,239 per hectare in 2001. Average prices of residential land per hectare were €2,175,000 in Sandhofen, €2,200,000 in Hochstätt and €2,100,000 in Strassenheim.[vi] Assuming that the market for land is sufficiently competitive, these prices equal the net present economic values of land in its respective uses. As explained above, recalculation of land prices is required, because the underlying time horizon of potential buyers is much longer than 10 years.

Appendix I shows the recalculations to yield the time-adjusted land prices for the example of restrictions in the Sandhofen project (the costs of the restrictions on the other residential projects have been calculated analogously). The ten-year prices of residential land in Sandhofen are €623,711 and €1,129,020 per hectare, and of agricultural land in Baden-Württemberg €5,517 and €9,987 per hectare in the low-cost and high-cost scenario. Given that we compare costs for the period between 2001 and 2010, the opportunity costs of the one-year delay in developing the residential land are equal to the foregone benefits of not developing in the first year. The corresponding land prices are €68,132 and €151,622 per hectare of residential land and €603 and €1,341 per hectare of agricultural land in the low-cost and high-cost scenarios. In Sandhofen, for the low-cost and high-cost scenarios respectively, the opportunity costs of modifications to development projects amount to

$$(\text{€}623{,}711 - \text{€}5{,}517) * 17.5 + (\text{€}68{,}132 - \text{€}603) * 6.4 = \text{€}11{,}250{,}581 \quad (5a)$$

$$(\text{€}1{,}129{,}020 - \text{€}9{,}987) * 17.5 + (\text{€}151{,}622 - \text{€}1{,}341) * 6.4 = \text{€}20{,}544{,}876 \quad (5b)$$

For Hochstätt and Strassenheim the ten-year prices of residential land are in the low-cost scenario €630,880, and €602,204 per hectare, respectively, and in the high-cost scenario they are €1,141,998, and €1,090,089. The resulting opportunity costs for Hochstätt are

$$(\text{€}630{,}880 - \text{€}5{,}517) * 10 = \text{€}6{,}253{,}630 \quad (6a)$$

$$(\text{€}1{,}141{,}998 - \text{€}9{,}987) * 10 = \text{€}11{,}320{,}110 \quad (6b)$$

Finally, in the low-cost scenario, the opportunity costs of the habitat reserve Strassenheimer Hof are obviously zero. In the high-cost scenario, these costs are

$$(\text{€}1{,}090{,}089 - \text{€}9{,}987) * 2 = \text{€}2{,}160{,}204 \quad (7)$$

Comparison of conservation costs

In the previous section, we have presented estimates on the costs of payments to landowners for species protection measures, costs of conservation management and the costs of rejecting, modifying, and delaying development projects. Although difficulties with data gathering prevented very accurate estimates, the results paint a very clear general picture, summarised in Figure 2.

Above we calculated that the estimated discounted value of the costs of compensation measures to landowners for conservation activities for a ten-year period is between €214,453 and €263,647, and the estimated discounted value of the costs of conservation management between €769,101 and €924,881. Together, the conservation costs with visible financial flows are between €983,554 and €1,188,528. The main cause of the difference between the two estimates lies with the different discount factors for the two estimation scenarios. The costs of modifying and delaying development projects amount to €19,585,447 and €38,297,548 in the low-cost and high-cost scenarios. For this cost type, the differences between the scenarios arise from both different parameter values and from different discount rates.

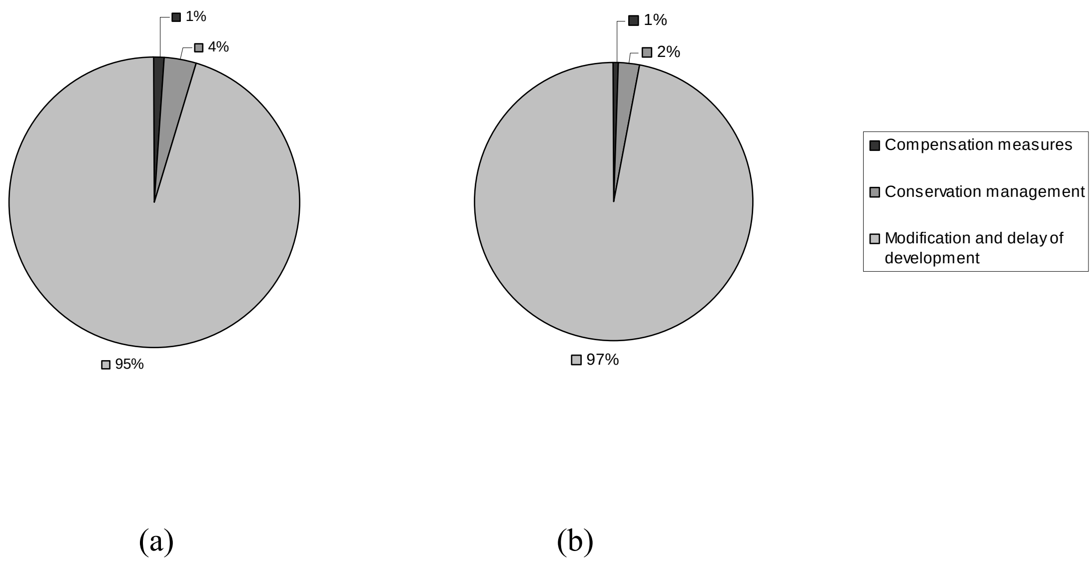

Figure 2. Relative contributions of conservation cost types to total cost for low-cost (a) and high-cost (b) scenarios

Figures 2(a) and 2(b) show the relative contributions of the three cost types to the total costs of hamster conservation in Mannheim. In the low-cost scenario, visible costs amount to 5% of total costs, whereas the less visible costs of changes to spatial planning make up around 95%. These contributions change to approximately 3% and 97%, respectively, when the high-cost scenario is considered. In our case study, conservation costs with no visible financial flows are more than an order of magnitude higher than conservation costs with visible financial flows. Even if we compare the high-cost scenario for visible costs with the low-cost scenario for less visible costs, the less visible costs are more than 16 times as high as the visible costs. In the other extreme comparison of the low-cost scenario for visible costs and the high-cost scenario for less visible costs, the less visible costs exceed visible costs by almost 38 times. Clearly, our case study demonstrates that the economic cost of having to change development projects for legally required conservation can be very high, but that only a small part of this cost is likely to be visible as a flow of money.

Discussion and conclusions

The Habitats Directive has led to the implementation of a variety of policy measures to conserve endangered species. These include species management programmes, payments to landowners for conservation measures and the delay, rejection and modification of economic development projects. We argued that the costs of conservation measures related to development projects are less visible than costs for other measures because there is no visible flow of financial resources. Consequently, there is a risk of underestimating the costs of changes in development projects.

We presented a framework to comprehensively assess the species conservation costs of measures that may be induced by the Habitats Directive and applied the framework to the case of hamster conservation in Mannheim (Germany), where the species is on the threshold of extinction. The EU Habitat Directive (EG 92/43/EEC) forced the local administration to introduce a multitude of policy measures in order to protect the local hamster population. Our results suggest that the conservation costs which are visible through monetary expenses are very low in comparison to those costs which are less visible because no expense is made, i.e., the opportunity costs of restrictions on development projects. Our estimates indicate that the discounted costs of compensation payments to farmers over a ten-year period are between €214,453 and €263,647, and the costs of conservation management are between €769,101 and €924,881. In comparison, we estimate that the less visible costs of modifying development projects are between €19.6 million and €38.2 million.

The status of the common hamster population in Germany today is very critical and we do not argue that the costly restrictions on economic development are not necessary. However, the fact that the main reason for the decline of the hamster population over the last decades has been changes in agricultural production and not a loss of agricultural land to other land uses suggests that the restrictions may not have been necessary if agricultural land use measures that support hamster populations had been applied *before* the species reached its critical status (cf. Kayser et al., 2003; Ulbrich and Kayser, 2004). This raises the question of the cost-effective allocation of financial resources over time (Drechsler and Wätzold, 2007), and further research may address whether for given financial resources it would have been better for the hamster population if conservation measures had started earlier.

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Appendix A. Derivation of net annual payments from land market prices

Let V be the market price of a parcel of land in any particular use at t=0, T the number of economically productive periods of that parcel in that use, and v_t the resulting constant net benefits in period t, then:

$$V = \sum_{t=0}^{T} \frac{v_t}{(1+\delta)^t}$$

$$V = v_t \sum_{t=0}^{T} \frac{1}{(1+\delta)^t}$$

$$v_t = V / \sum_{t=0}^{T} \frac{1}{(1+\delta)^t}$$

Finally, the net present value of v_t is given by $v_t/(1+\delta)^t$. All recalculations of land market prices have been performed using this formula, as illustrated below for the Sandhofen development project in the low-cost scenario. To calculate the costs of not developing the

Sandhofen area to a residential site, we assess the foregone benefits for the period between 2001and 2010, i.e., we reduce the time horizon from 50 years to the first 10 years:

$$V_{50} = €2{,}175{,}000 = \sum_{t=0}^{49} \frac{v_t}{(1+0.02)^t}$$

$$v_t = €68{,}132.39$$

$$V_{10} = \sum_{t=0}^{9} \frac{68{,}132.39}{(1+0.02)^t} = €623{,}711.10$$

For estimating the costs of the one-year delay in the Sandhofen development project, we calculate the foregone benefits of development for the first year in the ten-year period between 2001 and 2010

$$V_9^{delayed} = \sum_{t=1}^{9} \frac{68{,}132.39}{(1+0.02)^t} = €555{,}578.71$$

$$V_{10} - V_9^{delayed} = €68{,}132.39$$

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ENDNOTES

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[i] Recently, hamster nests have also been found near Heidelberg (Weinhold and Kayser, 2006).

[ii] We have based our list of affected projects on the spatial planning document of Mannheim, since this document contains official statements on the status of the hamster (SM, 2005b). The document can be downloaded from http://www.umweltforum-mannheim.de/download/doc/Boesfeld_EU_Beschwerdeg.doc.

[iii] See for instance: http://www.nachdenkseiten.de/cms/front_content.php?client=1&lang=1&idcat=9&idart=385 and http://www.wdr.de/online/news/hamster/index.phtml

[iv] http://q-park.co.uk/web/qparkuk.nsf/pages/ACCT_65GEKD.

[v] Some of these schemes are financed by IKEA and SAP Arena, but we have been unable to uncover the respective financial responsibilities of these companies. Our approach here has been to allocate all compensation payments to the administration of Mannheim, although this implies that management costs are slightly underestimated.

[vi] http://www.statistik.baden-wuerttemberg.de/Landwirtschaft/Landesdaten/kaufwert.asp.