# Comprehension of Conservation Costs in the Context of Wood Economy: a Case Study on Lesser Spotted Eagle Protection on Special Protection Areas

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*Abstract*

Modern forestry involves balancing multiple and often conflicting demands regarding the use and conservation of forest ecosystems. Protection of the Lesser Spotted Eagle (*Aquila pomarina* Brehm) and its nesting habitat in Natura 2000 sites is a good example of conservation solutions being directly connected to significant forest management restrictions. In Lithuania, the protection regime for the species in the Natura 2000 sites has been in place since 2004. However, neither the costs to the wood economy or the ecological benefits of the regime, or of alternative protection regimes, have been explored in detail. In this study, we aim to discuss a methodological framework to weigh up alternative regimes to protect the Lesser Spotted Eagle and its nesting habitat in the context of wood economy. We compared two approaches to protect the species and its habitat in three special protection areas (SPAs) designated for the Lesser Spotted Eagle. The current protection regime incorporates two types of measures: 1) for every estimated pair present in SPAs, two 3-5 ha mature forest stands are selected, along with protective zones 100 m wide around those stands. In the set-aside forest stands final felling is completely forbidden and other types of felling are restricted during the summer season. In the protective zones, all types of felling are restricted during the summer season, but permitted in other seasons; 2) For Lesser Spotted Eagle nests located outside the selected set-aside stands, final felling is restricted for a distance of 100 m around the nest throughout the year and other types of felling are also restricted during summer season. The Foundation for the Development of Nature Protection Projects has developed an alternative protection regime for this species in the SPAs. It is proposed to protect the mapped Lesser Spotted Eagle nest sites by: 1) restricting final felling within a 150 m throughout the year and 2) restricting all types of felling within 300 m during the summer season. Forest land and growing stock characteristics were made available for the case study area. Protection costs in terms of wood economy were associated with the average annual income decrease due to felling restrictions. We modelled the volume of growing stock at mature age and estimated the timber capital costs if no final felling is permitted. In the three SPAs, areas with strict forest use limitations according to the current protection regime covered 7.7% of the total area. During an intensive field inventory between 2011 and 2013, 48 nest sites occupied by the Lesser Spotted Eagle were identified, but only five nests were located in set-aside protected stands. The alternative protection regime involved shifting forests with forestry restrictions to relatively younger stands with a lesser area then subject to restrictions on final felling. The costs of the alternative protection regime were 44% lower per the protected Lesser Spotted Eagle pair than in the current regime. In this study, we demonstrated that both economic and ecological objectives would be better met if the Lesser Spotted Eagle protection regime were based on the actual distribution of breeding pairs in the SPAs. Also, we stress the need to involve a scheme of species distribution updates for any protective regime. Finally, we showed some implications that could be important for minimizing the costs and increasing the benefits for the conservation in practise of any forest-dwelling site-tenacious species and its habitat.

**Keywords**: alternative protection regime, birds of prey, forestry

## Introduction

The environmental and socio-economic role of forests is well understood and documented. Modern forestry should balance between multiple, sometimes conflicting demands regarding the use and conservation of forest ecosystems. Protection of nest sites of rare forest-dwelling birds is a good example of current challenges to forestry. Nest site selection influences reproduction and survival of individual birds and ultimately contributes to the regulation of bird populations (Johnson 2007). Forest-dwelling birds of prey usually prefer mature stands when selecting nest sites (Jędrzejewski et al. 1988, Boal and Mannan 1998, Suarez et al. 2000, Penteriani 2002, Sergio et al. 2003, Lõhmus 2006, Alexandrou et al. 2008), thus timber harvesting may negatively affect such species (Duncan 1997, Ewins 1997, Saurola 1997, Sulkava and Huhtala 1997, Widén 1997, Penteriani and Faivre 2001, Lõhmus 2003, Hakkarainen et al. 2008). Additionally, a tendency to return to a previously occupied location has been observed in the most long-lived territorial birds of prey (Jenkins and Jackman 1993, Poole 1989, Burnham et al. 2009). Therefore, management restrictions around nest sites occupied in successive years are useful tools for protecting nesting habitats and birds during periods of extreme sensitivity, such as incubation and nestling attendance (Richardson and Miller 1997, Lõhmus 2005). In widespread protected species, such restrictions inevitably generate considerable costs for resource managers, thus the evaluation of cost-effectiveness for alternative protection regimes is crucial in the socio-economic context.

The internationally protected Lesser Spotted Eagle (*Aquila pomarina* Brehm) (LSE) is a good example of a species challenging cost-effective solutions between nest site conservation and forest management due to its abundant nesting in the productive Central and Eastern European forests, which are an important subject of the wood economy. LSE is a long-lived, territorial bird that shows a high degree of nest site fidelity (Meyburg et al. 2004, 2005) and prefers to nest in mature forests and in old trees (Drobelis 1994, Skuja and Budrys 1999, Meyburg et al. 2001, Bergmanis 2004, Treinys and Mozgeris 2006, 2010). Habitat alteration caused by forestry is thought to be a critical threat to the European population (Meyburg et al. 2001). The EU 1979 Birds Directive, which was the first major law to address nature conservation on a European scale, is still the main legal framework for the protection of European birds (Carrete et al. 2006). In Article 4, it requires member states to designate the best sites for the rare or vulnerable species listed in Annex I (including LSE since 1985) as special protection areas (SPAs). Within SPAs, the member states are obliged to take necessary steps to avoid the deterioration of natural habitats and any disturbance of the species, where this disturbance would be significant having regard to the objectives of the Directive (Stroud et al. 2001).

In Lithuania, seven SPAs covering previously unprotected commercial forests were established in 2004 for the conservation of LSE. However, a significant part of the local population of LSE was unknown at that time. Currently, the key conservation measures in designated SPAs are i) the setting aside of two mature forest stands, each 3–5 ha in size (hereafter strict zones) for every pair present in the SPA, and ii) the creation of a 100 m buffer zone around the set-aside forest stands (hereafter summer zones). Final felling is forbidden in the set-aside forests stands, while other types of felling are restricted during the summer season. Final felling is also restricted within a 100 m distance around newly found Lesser Spotted Eagle nests following the requirements of the national Forest Felling Rules (2010). This protection regime is referred to in this paper as the current regime.

After extensive discussions involving numerous relevant stakeholders, the Foundation for the Development of Nature Protection Projects developed a new Lesser Spotted Eagle and its nesting habitat protection regime, hereafter termed the alternative regime. It encompasses the inventory of actual nest sites and proposes to use 150 m strict and 300 m summer buffers to restrict forestry activities. Below we shortly provide evidence for the rationale of this alternative conservation approach. Richardson and Miller (1997) indicated that human activities are known to impact raptors in at least three ways: i) by physically harming or killing eggs, young or adults, ii) by altering the habitats, and iii) by disrupting normal behaviour. A sound protection regime should overcome or prevent disturbance and habitat alterations that result in nest site abandonment or brood losses. A frequently exploited tool used by managers and police-makers is the creation of buffer zones around potentially sensitive centres of wildlife (Ruddock and Whitfield 2007). This tool fits well for the protection of raptors nest sites, when spatial and/or temporal restrictions are applied (Suter and Joness 1981, Lõhmus 2006, Penteriani and Faivre 2001). Recommended buffers vary in size depending on the species, topography, land use type and other factors (Suter and Joness 1981, Richardson and Miller 1997, Ruddock and Whitfield 2007), but it is essential that the buffers are of adequate size for effective conservation. The alternative protection regime discussed in the current paper gives protection to mapped Lesser Spotted Eagle nest sites using a two-buffer system, which is a highly effective method to protect nests and broods of birds of prey (Sielicki and Mizera 2009). A strict buffer of 150 m was chosen to prevent alteration to the nesting habitat patch (Treinys et al. 2009), while the second buffer ring (covering an area of 150 m to 300 m around the nest, hereafter termed the summer buffer) is supposed to prevent brood losses (for detailed information on the alternative regime see in Methods). A pair of long-lived raptor uses several nests within a definite territory from year to year (Newton 1979). Due to limited budget and human resources, it is unrealistic to monitor nest change for each breeding pair within the SPAs on an annual base, thus extra limitations on forestry activities need to be applied around the strict buffer to prevent brood losses during the breeding season before alternative nests have been mapped and protected. R. Treinys (unpublished) found that Lesser Spotted Eagles in Lithuania occupy available nests or build new nests close to the old ones: 71% of nest change occasions being located within 300 m of the old nest.

Although these conservation measures are likely to reduce the timber supply from indicated forests, there has been no previous attempt to estimate the efficiency neither of the adopted conservation approaches for the species nor of any alternative conservation regimes, discussing the benefits and related costs for Lithuanian forestry and the Lesser Spotted Eagle conservation.

In the context of sustainable forestry, forest policy tools should be directed towards harmonizing the use of all forest products and services. However, maximization of the total value of forest ecosystems requires all the products and services to be quantified using comparable dimensions (Glück 2000). The costs of forest habitat protection are usually measured as an income decrease due to management restrictions (Jeffrey 2003, Rosenkranz et al. 2014). The quantification of benefits is more complicated and can be conducted using different methods based on revealed preferences, such as travel cost method and hedonic price method, or stated preferences, such as contingent valuation and choice of experiment method (Bartczak et al. 2009, Riera et al. 2012). When several habitat protection/conservation regimes are compared, estimation of opportunity costs is one of the most popular tools for decision making (Bergseng et al. 2012). This approach has been used by various authors to assess the habitat protection/conservation impact, e.g., in Germany (Rosenkranz et al. 2014), Finland (Leppänen et al. 2005) and Croatia (Posavec et al. 2011).

This paper aims to demonstrate the advantages of opportunity-cost analysis for the LSE conservation by identifying the protection regime that has the greatest effect for a given cost. This is measured by comparing the biological impact (benefit) and the action costs (Gjertsen et al. 2014), the latter being expressed in terms of incurred reduction of income from timber harvesting. Two approaches for protecting Lesser Spotted Eagle and its nesting habitat are compared in three special protection areas in Lithuania. The first one is based on the current conservation measures in the designated SPAs; the other refers to an elaborated alternative regime involving a more flexible and dynamic selection of target sites for conservation. Recent field information on occupied Lesser Spotted Eagle nest sites, as well as detailed information on forest characteristics in the respective SPAs, were used to facilitate the evaluation. As both approaches involve costs for the Lesser Spotted Eagle monitoring, they are also discussed in the paper.

## Material and Methods

***Study areas conservation regimes and fieldwork***

Three special protection areas (Gubernija, Gedžiūnai and Šimonys forests) designated for Lesser Spotted Eagle protection were chosen for the study (Fig. 1a). Their total forest land area is ca. 42 000 ha, including over 39 000 ha of forest stands. The predominant tree species are pine (32%), birch (28%) and spruce (27%), accompanied by black and grey alder, aspen (3% each), oak and ash (1% each). To protect LSE and its nesting habitat in the SPAs the following strategy (*current regime*) was adopted in 2004: for each estimated pair, two *strict zones* with their *summer zones* (i.e. the areas where restrictions were applied during the breeding season only) were selected based on known nest sites where possible (Figure 1b and Figure 2a). Additional strict zones were selected based on forest characteristics (e.g. tree species composition, maturity etc., apparently suitable for species), where known nest sites were lacking. The established network of strict zones and corresponding summer zones is static: no mechanism was foreseen to adjust the network of zones according to the actual distribution of nesting birds. If a new nest site of Lesser Spotted Eagle is mapped, a strict protection regime then applies to the areas inside 100 m buffer zones around the nest sites if they are identified outside strict zones according to the Forest Felling Rules (2010). As the primary unit of forest management planning and forestry operations in Lithuania is a forest compartment, the 100 m distance can be shrunk or expanded by up to 25 % to align the buffer to the borders of compart-

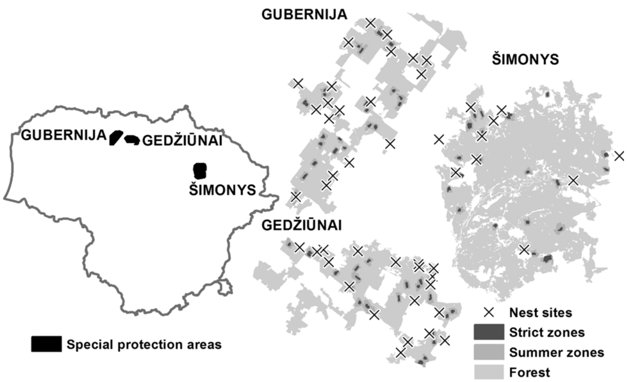


**Figure 2.** Forest under management restrictions to protect the Lesser Spotted Eagle: a) current conservation regime, b) alternative conservation regime

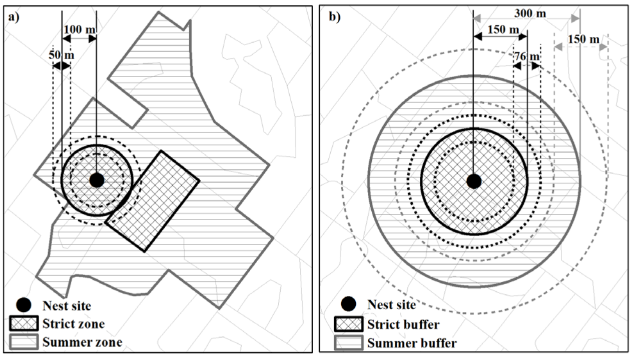


**Figure 2.** Forest under management restrictions to protect the Lesser Spotted Eagle: a) current conservation regime, b) alternative conservation regime

ments. In general, such a binary protection regime nowadays is applied for the conservation of the species and its nesting habitat within the SPAs.

The alternative regime is based on the protection of field-identified nest sites within two circular buffers: 150 m and 300 m. Shrinkage and expansion of both buffer distances by 25 % are assumed here as well, to align the borders of buffers and forest compartments. The network of nest sites protected by applying the two buffers is dynamic: abandoned nest sites are excluded, while new ones may be included in the network as actual information becomes available (for a proposed monitoring-inventory scheme, see Discussion).

LSE nest sites were searched for in the SPAs between 2011 and 2013. Two complementary methods were used. First, occupied territories were mapped between April and August according to the birds' behaviour observed using binoculars (8 × 42) and telescopes (20–60 ×) from forest edges (for a detailed method description and justification see Ivanovski and Bashkirov 2002, Dombrovski and Ivanovski 2005). Then, nests were searched for in mapped territories between July and March. The coordinates of each nest site were GPS recorded and stored in a GIS database.

### *Data analysis*

Information on all forest compartments in the SPAs was made available by the State forest cadastre, including the borders of compartments and all conventional descriptive stand characteristics. As that information originates from standwise forest inventories in different years over the last decade, it was updated using growth models (Kuliešis 1993) and data on silvicultural treatments to represent the year 2013.

The available geographic information on the designated network of strict and summer zones was supplemented with a 100 m buffer with ± 25% shrinkage/expansion areas around the nest sites to represent the strict conservation area due to the requirements of the Forest Felling Rules. According to the alternative regime, buffers (i.e., 150 m and 300 m) could shrink/expand by up to 25%, i.e. from 112 to 188 m and from 225 to 375 m for strict and summer buffers respectively. Thus, around each eagle nest site identified during fieldwork, three buffers (112, 150, 188 m) were generated using conventional GIS buffering techniques to represent full-range strict buffer shrinkage and another three buffers (225, 300, 375 m) for summer buffer shrinkage (Figure 2b). Forest compartments with associated attributes were clipped out using: i) strict zones, ii) summer zones, iii) strict buffers, and iv) summer buffers.

Protection costs were estimated for the commercial and protective forests (forest groups 4 and 3 respectively, using the Lithuanian forest grouping system); the incomes from group 2 forests (special purpose forests) were considered as unchanged due to Lesser Spotted Eagle protection. Protection costs in terms of wood economy were interpreted as decreases in average annual income due to felling restrictions, which was estimated i) by modelling the volume of growing stock at maturity, and ii) by estimating the timber capital costs if no final felling is permitted in forest compartments or parts of compartments belonging to the respective area (zone or buffer, depending on the conservation strategy) with management restrictions. The volume of growing stock at maturity, which is associated with the final felling age in Lithuanian forestry, was estimated depending on the actual age of the stand:

- For mature and overmature stands, the actual volume of the growing stock was used.
- For non-mature but older than 30 years forest stands, the potential growing stock volume at an age of 100 years ($P$) was modelled first, then the volume at final felling age ($M_K$) was estimated using an approach introduced by A. Tebėra (1987):

$$P = \frac{M}{a_0 + a_1 t + a_2 t^2} \tag{1}$$

where: $M$ – current volume of growing stock, available from the attributes of the forest compartment, m³/ha; $t$ – current age of the stand; $a_0$, $a_1$, $a_2$ – parameters available from A. Tebėra (1987) and depending on the prevailing tree species.

$$M_K = P \times (a_0 + a_1 T + a_2 T^2) \tag{2}$$

where: $T$ – final felling age, years.

- For the stands younger than 30 years, we used the average actual growing stock volume of all currently mature and overmature stands in selected SPAs by prevailing tree species and site index, available from the State Forest Cadastre.

Next, the diameter at the age of maturity for all tree species in the stand was estimated:

• For mature and overmature stands, the actual diameter of all tree species was used.

• For other stands, the average diameter of currently mature and overmature stands in selected SPAs by prevailing tree species and site index, available from the State Forest Cadastre, was used.

Timber price was calculated by tree species and their average diameter:

$$K_r = a_0 + a_1 \times Dr + a_2 \times D_r^2 \quad (3)$$

where $K_r$ – timber price of *r* tree species, Lt/m³; $D_r$ – diameter of *r* tree species, cm; $a_0$, $a_1$ and $a_2$ – parameters defining the relationship between timber price and tree species and diameter (Table 1), modelled using current timber market prices (year 2013) (http://www.gmu.lt).

**Table 1.** Model parameters defining the relationship between timber price by tree species and diameter

| Tree species | $a_2$ | $a_1$ | $a_0$ |
|---|---|---|---|
| Pine | -0.112 | 8.0935 | -40.161 |
| Spruce | -0.0847 | 6.7595 | -29.049 |
| Oak | -0.2406 | 19.635 | -94.493 |
| Ash and other hardwood deciduous | -0.0109 | 2.2619 | 24.909 |
| Birch | -0.0821 | 6.7511 | -33.619 |
| Black alder | -0,0466 | 3,8786 | -9,2487 |
| Aspen and other softwood deciduous | -0.0301 | 2.1459 | 1.0232 |
| Grey alder | -0.0142 | 1.7532 | -2.8924 |

The annual timber capital cost if no final felling is permitted ($V_c$) was calculated as:

$$V_c = R_l \times 0.03 \quad (4)$$

where: $R_l$ – the value of timber restricted from final felling, EUR; 0.03 – interest rate (3%).

$$R_l = \Sigma M_{kr} \times K_r \quad (5)$$

The present value of the average annual income decrease due to felling restrictions, $V_m$, depends on the age of the stand:

• For the undermature stands:

$$V_m = V_c / (1.03)^{(T-t)} \quad (6)$$

• For mature and overmature stands:

$$V_m = V_c \quad (7)$$

The value of forest land and currently available timber as well as the average annual income decrease due to felling restrictions per nesting LSE pair were calculated in the following way:

• Current protection regime – the total value of strict zones plus the total value of 0-100 m strict buffers and the sum divided by 48 (the number of nesting pairs). The sum before division was adjusted for the area of overlapping strict zones and 0-100 m strict buffers;

• Alternative protection regime – the total value of 0-150 m strict buffers divided by 48.

ArcGIS and MS Excel were used to manipulate the data and perform all the calculations.

Additionally, the value of forest land and currently available timber was estimated following the methodology of "Guidelines to Assess Land Value" by the Government of the Republic of Lithuania, which is based on the average value of forest land by site types and the average value of standing timber by tree species and average diameter. All prices were converted into Euro.

## Results

Ca. 38 pairs of Lesser Spotted Eagle were estimated to have bred in Šimonys, Gedžiūnai and Gubernija SPAs before the year 2004, when the current protection regime was established. This resulted in a total of 76 strict zones with their summer zones in the SPAs. However, during intensive fieldwork, nest sites of 48 Lesser Spotted Eagle pairs were identified. Thus, the earlier underestimation of the population was 26%. Moreover, in 76 designated strict zones only five (10.4%) out of 48 identified nest sites occupied by Lesser Spotted Eagles were found.

The total forest land area in the 76 strict zones with final felling restrictions was 397 ha, while forest land area in the 150 m strict buffers around the 48 actual nest sites covered 316 ha (Table 2). Forest land area in the strict zones ranged from 1 to 29.3 ha, on average 5.22 ha ± 3.72 ha SD (n=76). The alternative protection regime, even including shrinkage by 25%, resulted in less variable forest area in the strict buffers (3.8-11.1 ha, mean 6.59 ha ± 0.81 ha SD; n=48). A relatively older forest was found in strict zones. The alternative protection regime involved doubling the share of young stands (the share of area of stands younger than 50 years increased from 13 to 27%) and decreasing the share of older stands (the share of volume of mature and over-mature stands was 86 and 59 % in strict zones under current and alternative regimes respectively) with forestry restrictions, thus reducing the area and growing stock volume not available for final felling in the immediate future.

The average annual income decrease due to final felling restrictions per 1 ha was the largest in the current strict zones, 149 EUR/ha (Table 3). With the alternative regime, the income decrease tended to go down with the increasing strict buffer zones (148, 140 and 133 EUR/ha, for 112, 150 and 188 m buffer zones respectively). The total annual income decrease due to final felling restrictions in the current strict zones and strict 100 m buffers amounted to 79,040 EUR. The income decrease for the alternative protection regime would be 44,425 EUR. The average values per one nesting LSE pair were

**Table 2.** Characteristics of forest stands important for protection of the Lesser Spotted Eagle

| Parameter | Current regime | | | | | Alternative regime | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Strict zones | Summer zones | Strict buffers | | | Strict buffers | | | Summer |
| | | | 0-75 m | 0-100 m | 0-125 m | 0-112 m | 0-150 m | 0-188 m | 150-225 m |
| Forest area, ha | | | | | | | | | |
| Total | 396.92 | 1979.56 | 83.3 | 145.9 | 223.9 | 181.50 | 316.24 | 480.22 | 347.30 |
| Average per site | 5.22 | 26.05 | 1.73 | 3.04 | 4.66 | 3.78 | 6.59 | 10.00 | 7.24 |
| Private forest area, ha | | | | | | | | | |
| Total | 79.1 | 270.4 | 22.3 | 38.9 | 58.7 | 48.0 | 81.2 | 116.3 | 58.7 |
| No of sites | 9 | 26 | 18 | 18 | 20 | 20 | 21 | 22 | 24 |
| Volume of the growing stock, all forests, 10 m³ | | | | | | | | | |
| Total | 9083 | 34422 | 1707 | 2927 | 4388 | 3602 | 6037 | 8836 | 5736 |
| Average per site | 119.5 | 452.9 | 35.6 | 61.0 | 91.4 | 75.0 | 125.8 | 184.1 | 119.5 |
| Volume of the growing stock, mature and overmature forests, 10 m³ | | | | | | | | | |
| Total | 7788 | 16705 | 1200 | 2011 | 2928 | 2440 | 3934 | 5523 | 3114 |
| Average per site | 102.5 | 219.8 | 25.0 | 41.9 | 61.0 | 50.8 | 82.0 | 115.1 | 64.9 |

**Table 3.** The Lesser Spotted Eagle habitat conservation costs

| Parameter | Current regime | | | | | Alternative regime | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Strict zones | Summer zones | Strict buffers | | | Strict buffers | | | Summer |
| | | | 0-75 m | 0-100 m | 0-125 m | 0-112 m | 0-150 m | 0-188 m | 150-225 m |
| Average annual income decrease due to final felling restrictions, EUR | | | | | | | | | |
| Total | 62843 | | 16525 | 23354 | 34685 | 28621 | 47156 | 67632 | |
| Average per site | 827 | | 344 | 487 | 722 | 596 | 983 | 1409 | |
| Average annual income decrease due to final felling restrictions on private forests, EUR | | | | | | | | | |
| Total | 10505 | | 4063 | 5218 | 7758 | 6400 | 10526 | 14659 | |
| Land value according to the methodology by the Government of the Republic of Lithuania, EUR | | | | | | | | | |
| Total | 83853 | 417577 | 18127 | 31706 | 48677 | 39457 | 68723 | 104361 | 75261 |
| Average per site | 1103 | 5494 | 378 | 661 | 1014 | 822 | 1432 | 2174 | 1568 |
| Timber value according to the methodology by the Government of the Republic of Lithuania, EUR | | | | | | | | | |
| Total | 1050329 | 3550295 | 202870 | 339515 | 497201 | 412818 | 669920 | 950452 | 562983 |
| Average per site | 13820 | 46715 | 4227 | 7073 | 10358 | 8600 | 13957 | 19801 | 11729 |

1647 and 926 EUR respectively. Thus, the alternative protection regime would result in 44% reduction in annual decrease in income from timber per Lesser Spotted Eagle pair in the study areas.

Land value was found to be similar for both protection regimes. The average value was nearly the same in the strict zones and their summer zones (~199 EUR/ha), while it was slightly higher in the areas selected under the alternative regime (204–205 EUR/ha, depending on the buffer zone). The total value of land under the current strict protection regime was 106,176 EUR, resulting in an average value per one nesting LSE pair equal to 2212 EUR. The value of land per one nesting pair if the alternative protection regime was applied would by 1349 EUR, or 39% less.

The calculated value of timber was 2493 Eur/ha in the strict zones of the current regime. Under the alternative regime, the smaller was the strict buffer, the larger was the average per-hectare timber value, i.e., it declined along with the distance from the nest site (2143, 1996, 1865 EUR/ha for 112, 150 and 188 m buffer zones, respectively). The total values of timber in forest stands located in strictly protected zones were 1,276,776 and 631,115 EUR, or 26,600 and 13,148 EUR per nesting pair, assuming current and alternative protection regimes, respectively.

Only 20% of the forests inside the strict zones were privately owned, while the share of private forests in the total SPAs chosen for the study was 35%. The share of private forests in the zones with final felling restrictions would increase up to 26% if the alternative regime was applied. This would result in nearly the same annual income decrease for private owners as that under the conditions of the current regime.

## Discussion and Conclusions

Paradoxically, the current protection regime has resulted in most breeding pairs being protected, namely under the Forest Felling Rules, by a relatively small strict buffer (100 m ±25%) and thus are weakly protected against disturbance during the breeding season as the Final Felling Rules do not include an additional summer buffer. Furthermore, this study has demonstrated that both economic and ecological objectives would be better met if the Lesser Spotted Eagle protection regime would be based on the actual distribution of breeding pairs. The current protection regime assumes strict forest management restrictions on at least 530 ha. This includes all strict zones established to protect 38 pairs that were thought to have bred in Šimonys, Gedžiūnai and Gubernija SPAs before the year 2004 and, additionally, strict buffers (100 m) around the nest sites of 43 identified pairs. This figure exceeds even the potentially largest forest area for strict buffers around the occupied nests of 48 pairs (i.e. 480 ha in the case of 188-m buffers). In reality, the largest size buffers would obviously not be applied throughout the territory. However, this rationale becomes more complicated, when one considers actual costs in the context of the wood economy, subsidies and forest reallocation. Estimation of the costs requires precise information on forest resources and a methodological framework for economic evaluation of alternative protection approaches in addition to ecological considerations.

From a pure economist's point of view, the valuation of forest protection costs can be based on the calculation of income loss in wood production expressed in net present value. We estimated the total annual income decrease due to final felling restrictions at 1,647 EUR per each breeding pair. This is nearly 1.8 times higher than for the alternative protection regime. Around 70% of the income decrease under the current protection regime is associated with final felling restrictions in the strict zones, which are marginally used by species. The current protection regime is based on setting aside from final felling large timber volumes, with ~86% of the volume concentrated in the category of mature and overmature forest, compared with ~65% in strict buffers of the alternative regime.

We admit, however, that some details of valuation techniques remain under discussion, e.g., scope and subject, time horizon, choice of interest rate, forecast of costs and revenues, etc. In the current study, the calculations were conducted at the nest site level, not at regional or ownership levels as discussed by Leppänen et al. (2005), habitat type within a forest enterprise (Rosenkranz et al. 2014) or whole forest enterprise (Posavec et al. 2011) levels. The nest site level is more practical for the choice of regimes in our case, but it can also be successfully applied to make a comparison between protection costs in different study areas as well as to forecast and plan the protection expenditures. The choice of time period for the valuation of income loss can be based on either forest rotation (Posavec et al. 2011), perpetual or terminated annuity (Leppänen et al. 2005, Rosenkranz et al. 2014). In our study, the main emphasis is put on the decrease of annual income, as this indicator is directly related to cash flows of forest enterprises or private holdings, and can be easily understood by forest managers, owners and other decision makers. An interest rate of 3% was used in the calculation, which is the traditional discount rate used in forestry and is close to the long-term real interest rate. Though Brukas et al. (2001) suggest 0-2% interest rate for the East European forestry because of age-dependent externalities, the higher interest rate was chosen as only timber income was evaluated in this study Alternatively, an enterprise interest rate (Rosenkranz et al. 2014) or internal rate of return from forest rotation (Posavec et al. 2011) can be used. The fair value of protection costs is usually based on current market prices (Posavec et al. 2011, Rosenkranz et al. 2014, Gjertsen et al. 2014). Land and timber value according to the methodology of the Government of the Republic of Lithuania, used in the current study as one of additional options for comparing between the two LSE protection alternatives, was based on nominal prices determined by legal acts and thus did not reflect current market prices. This is avoided by using the annual income decrease as an indicator both to compare between alternatives and to support further decision making.

Altogether we identified three major gaps in the current protection regime in the studied SPAs: i) a low incidence of occupied nest sites in the selected network of strict zones, ii) the static pattern of the selected network and absence of nest site inventory schemes, and iii) insufficient protection of occupied nest sites. In theory, a species and habitat protection regime should reach maximum efficiency, when all occupied nest sites are covered by protected zones within a target area. We found, however, the efficiency to be very low because only 10.4% of mapped nest sites were located in selected strict zones. We suggest several complementary reasons for this result. First, a detailed inventory of LSE nest sites in SPAs was not conducted beforehand and the most of the strict zones were selected based on stand characteristics (i.e. similarity to the eagle's nest sites elsewhere in the country; author's data). Secondly, forest patches suitable for the LSE are still abundantly available in three SPAs as well as in surrounding forests (Mozgeris and Treinys, unpubl.). Thirdly, occupation of potential nesting habitat patches could be constrained by biological interactions such as inter- and intraspecific competition or intraguild predation (Hakkarainen et al. 2004, Krüger 2002, Katzner et al. 2003, Sergio and Hiraldo 2008). Forecasting biological interaction, however, is rather complicated or even unrealistic in areas not subjected to schemes of long-term raptor research. Fourthly, LSE within definite territory use several nests located several hundred of meters from each another in various years (Meyburg et al. 2004). Thus, some protected forest patches were abandoned due to nest site turnover.

The most protection regimes will lose their effectiveness in the long run if they are not updated with information. Of course, nest site inventory schemes will result in additional conservation costs. The current protection regime is accompanied with a monitoring scheme involving counting of eagles at selected points (see Ivanovski and Bashkirov 2002, Dombrovski and Ivanovski 2005) in SPAs every three years (for details see Table 4.). It focuses on the monitoring of population number and dynamics; however, neither breeding success and exact number, nor exact locations of nest sites are indeed covered. The alternative regime proposed to interlink a monitoring (monitoring-inventory) scheme developed based on nest site turnover pattern and field experience on species research (Treinys unpublished). It includes two complementary methods, namely counting of eagles from selected points during the breeding season (see Ivanovski and Bashkirov 2002, Dombrovski and Ivanovski 2005) and nest-site search. One-phase field work (there are two phases during the 10-year cycle) are conducted in two years to overcome weather and breeding success fluctuations, as well to improve nest site search efficiency during the non-vegetation phase. The proposed scheme includes flexible possibility to reallocate fieldwork intensity between years. To have the monitoring costs compared between the present and proposed schemes, we estimated demand for manpower per one phase and for the whole 10-year cycle in three SPAs (Table 4). Manpower required to implement the field work covers approximately half of total monitoring costs, while the rest of the costs are related to the travel, accommodation, equipment, administration costs, etc. However, other costs are proportionally related to manpower costs, so they have little influence in comparing the two schemes. For illustrative purpose, we estimated demand to cover man power costs for the alternative monitoring – the inventory scheme for three SPAs per 10 years. We calculated 21,000 EUR (i.e., 300 man days × 70 EUR / man day), a figure equivalent to ~ 5 % of income decrease due to forest felling restriction within the three study areas over 10 years.

The proposed alternative protection regime involves a monitoring scheme demanding up to 53 % more manpower. There are also other intangible factors, which need to be considered while comparing the two monitoring schemes (Table 5.). As a disadvantage of the alternative monitoring scheme, its sensitivity to the experience of fieldworkers and knowledge of the species could be considered. However, it is much appropriate in terms of knowledge on overall species status and conservation of actual nesting habitat in SPAs. Moreover, the research quality in terms of pair numbers and dynamics is expected to be higher due to extensions of one-phase works for two years. The monitoring-inventory scheme could be applied for the protection of nest sites of large, site-tenacious mature forest-dwelling birds such as White-tailed Eagle, Osprey, Black Kite and Black Stork. These species are distributed in considerably lower densities than the LSE in the Lithuanian SPAs designated for these species. Thus, information updates on occupied nest site distribution for the adjustment of the protection network for these species over several years will require less manpower and costs than calculated for LSE and could be realized taking into consideration human capacity and costs in Lithuania. Honey Buzzard nest site preferences are marginally related to the forest age (Selås 1997, Gamauf et al. 2013). Considering also their

**Table 4.** Timetable and demand for manpower to implement the Lesser Spotted Eagle monitoring in Šimonys, Gedžiūnai and Gubernija SPAs during the 10-year cycle under conditions of current and alternative monitoring schemes

| 10-year cycle | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Regime | 1y | 2y | 3y | 4y | 5y | 6y | 7y | 8y | 9y |
| Current | ■ | | | ■ | | | ■ | | |
| Man days | 49-74 | | | 49-74 | | | 49-74 | | |
| Alternative | ■ | ■ | | | | ■ | ■ | | |
| Man days | 100 | 50 | | | | 100 | 50 | | |

**Table 5.** Expert based comparison of monitoring schemes associated with current and alternative protection regimes 10-year cycle in Šimonys, Gedžiūnai and Gubernija SPAs

| Variable | Current | Alternative |
|---|---|---|
| Manpower per 10-year cycle | 196 – 294 man days | 300 man days |
| Data quality | | |
| Estimation of population number | Moderate | High |
| Estimation of breeding success | Poor | High |
| Estimation of threats | Moderate | High |
| Importance for nesting habitat conservation | Poor | High |
| Dependence of weather conditions | High | Moderate |
| Dependence of the breeding success | High | Moderate |
| Qualification | Moderate | High |

cryptic behaviour (Selås 1997) and abundance of species, we suppose that the conservation of Honey Buzzard and its nesting habitat within SPAs in Lithuania through mapping and protection of occupied nest sites is not a suitable strategy.

To conclude, the proposed alternative protection regime strategy would result in 44% lower decrease in income from timber per LSE pair in the study areas compared to the current one, while at the same time being ecologically more sound for species and its nesting habitat conservation. We have demonstrated a methodological framework for the evaluation of alternative habitat protection regimes, taking into account conservation costs and benefits in terms of wood economy. Based on the findings of this study, we suggest several implications that could be important for minimizing the costs and increasing the benefits of species and its habitat conservation:

- an inventory of the actual distribution of species should be done before the adoption of any protection regime, which has significant socio-economical costs to avoid resource wasting;
- in the case of site-tenacious, territorial, sparsely distributed species, the conservation of nesting habitats should rely firstly on protection of occupied nest sites;
- protection of potential nesting habitats by setting aside apparently suitable patches could be additionally applied if they have proved population limitation due to lack of habitat;
- ongoing updating or monitoring of protection units (e.g., nest sites) should be part of a protection regime to keep management restrictions and income decreases ecologically meaningful in the long term;
- the evaluation of conservation costs per one identifiable protection unit provides an economically supported choice among several ecologically sound conservation alternatives and supports allocating the costs for target areas, distributing them by ownership, etc.;
- the estimation of conservation costs should be based on approaches assuming actual market prices for a certain ecosystem service, such as annual income decrease due to forestry restrictions, rather than those involving nominal pricing determined by legal acts.

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