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A multi-level system for planning compensatory habitats as a new tool to prevent biodiversity loss in protected areas due to development plans

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List of any nonstandard abbreviations
Appropriate assessment(s) – AA
Compensatory habitat(s) – CH
Program for Multi-Attribute Decision Making – DEXi
Multi Criteria Decision Analysis – MCDA

Abstract

Background

In Slovenia, compensatory habitats (CH) are currently determined on the basis of a subjective expert judgement and without using any clearly defined methodology, due to which the success rates of their implementation are low. The aim of this research is to fill in a methodological gap and propose a new multi-level system for planning CH. The system should enable a transparent and more objective determination of the size of a CH in the processes of appropriate assessments (AA).

Materials and methods:

*The system was developed by using a multi criteria decision analysis, a multi-attribute decision support model and the DEXi modelling tool. It was tested on a study case the Škofljica bypass road with its impact on the Whinchat (*Saxicola rubetra*) at the Natura 2000 site Ljubljansko barje.*

Results:

The system with three modules and a possibility of what-if analysis was developed to assess the species endangerment and the size of the CH. The results of the assessment showed that the case study has significant impacts to the Whinchat, therefore the CH of a slightly larger size than the habitat lost was proposed. In addition, the system indicated that only one of the three potential locations of the CH is suitable for implementing the CH.

Conclusions:

The system allows a transparent and more objective assessment of the spatial plan. It is a new, easy-to-use, adjustable, cost- and time-efficient method that can be used to make reliable and transparent decisions during the assessment processes.

Keywords:

Natura 2000; Offsetting; Ecological compensation; Habitat (re)creation; Appropriate Assessment; Sustainable development

INTRODUCTION

Ecosystems are deteriorating worldwide and nearly a quarter of species are threatened with extinction (1). One of the main reasons for such state is habitat loss (1), which is caused by urban sprawl, agricultural intensification and intensively managed forests (2).

One of the most organized processes created in Europe to halt the loss of biodiversity is the establishment and management of the Natura 2000 network. The network is based on the implementation of the *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora* (the Habitats Directive) and *the Directive 2009/147/EC of the European parliament and of the council of 30 November 2009 on the conservation of wild birds* (the Birds Directive). The aim of the Natura 2000 network is to maintain or increase species populations and the extent of natural habitats of wild fauna and flora of Community interest (3). One of the ways to achive this is also by fulfilling the requirement to appropriately assess plans or projects that might have a significant impact on a Natura 2000 site and to mitigate their negative impact in the view of the site's conservation objectives (4).

The significant impacts of spatial plans on biodiversity can be compensated by biodiversity offsets, i.e. interventions made to compensate for the habitat loss with another equivalent or better habitat (4). The size of a compensatory habitat (CH) should be determined according to the principle of no net loss of biodiversity (5). The use of habitat banking is gaining acknowledgement internationally as a strategy to ensure a CH before the plan is designed (6).

The CH is becoming an increasingly popular and widely accepted intervention for the conservation of biodiversity as it also allows for economic development. While the simplest methods for defining the CH have been taking into account only the surface area of the lost habitat, the more sophisticated models also include habitat condition, habitat value and species abundance. In practice, however, the vast majority of all CH implementations are not as effective as expected (7, 8, 9, 10, 11). Due to differences in methods, the CH are usually vaguely calculated and most often determined by subjective professional judgement, which results in low success rate of the CH implementation (11, 12, 13, 14, 15). Bull et al (16) compared different methods for calculating the required CH in the same case study. Their study showed that methods can result in a range of different sizes of CH. Bull et al (16) conclude that choosing the most appropriate method to calculate a CH strongly affects the success rate of the CH implementation and reaching the objective of no net loss of biodiversity.

To determine a CH objectively, it is necessary to develop a method based on data describing the surface area and the condition of a habitat lost and a CH, as well as the abundance and conservation status of species and their habitats. The method should allow to assess the impact of the CH's size on the species population. Since the availability of such data are limited, most of the current methods are based on the data about the surface area and conditions of the lost habitat, while using risk multipliers that are mostly determinted subjectively (11).

Risk multipliers are commonly used to adjust (generally increase) the CH size and compensate for the risk of unsuccessfully implementing a CH. The risk multiplier is based on the empirical analysis of the success rate of similar CH or determined through consultations and negotiations with the stakeholders (17). According to the literature (7, 9, 18, 19), risk multipliers can vary widely. They represent the ratio of the area of lost habitat to the size of proposed CH that can range from 4:1 (the area of a CH is four times smaller than the area of the lost habitat) to 1:125 (area of a CH is 125 times bigger than the area of lost habitat). There are differences in the CH calculation methods among countries as well as among regions within the same country (11). Because different methods were used, different risk multipliers were applied for the same species in similar habitats (20, 21). In addition to the challenges concerning the objective calculation of the CH area size, the guidelines regarding the timing needed for the CH implementation, long-term management and monitoring are also unclear (9, 18, 22, 23).

Various methods for calculating the CH size have been used also in Slovenia. When the first CHs were determined, risk multipliers were not used (e.g. 24, 25, 26). After the King and Price's research (9) had been published, numerous Slovenian authors (e.g. 27, 28, 29, 30) started to use their risk multiplier 1:1,4. Due to the high rigidness of such fixed multipliers, additional elements for determining the CH have been introduced and risk multipliers in Slovenia today range from 1: 1,1 to 1: 1,5 (e.g. 31, 32; 33, 34). Ecological modelling has not yet been used for the determination of a CH in Slovenia.

The aim of our research was to develop a multi-level system for the determination of CH. The first objective was to develop a model to determine if a CH is an appropriate measure to halt the negative impacts that implementation of spatial plan might have on diversity and habitat quality. Second goal was to develop a model for the prediction of the risk multiplier. The developed system should be applicable to protected species from terrestrial habitats exposed to different environmental conditions. Its use should be simple, time- and cost-efficient, and administratively rational. The system should allow the user to discuss and explain the reasoning behind the decisions made. In this way, the system could become interesting for evaluators, investors and decision-makers, and support the multi-stakeholder approach to the effective implementation of CH.

MATERIAL AND METHODS

3.1 Tools used for developing the system

Defining a CH is a complex decision-making problem, which requires a structured approach to developing a new multi-level system for planning CH. The models that are integrated into a system were developed by using Multi Criteria Decision Analysis (MCDA) (35) implemented in the DEX (Decision EXpert) methodology (36) that we used to build qualitative multi-attribute decision models with the DEXi modelling tool (37). The MCDA allowed us to decompose a complex decision-making problem into less complex decision-making subproblems. An individual subproblem is described with a set of qualitative criteria for defining CH. The criteria are hierarchically structured into a decision tree using integration roles described in utility tables. The utility table includes all combinations of values of the child attributes that are integrated in the values of an aggregated (e.g. parent) attribute. The values of the root attribute (e.g. the top attribute in the hierarchical decision tree) represent the set of the final outputs from the model (e.g. the CH size). All attributes used in qualitative multi-attribute models have a finite set of qualitative values (e.g. inappropriate, acceptable, and excellent).

To obtain and analyse spatial data, we used the ArcGIS's spatial information systems. With this tool, we visualized areas included in our research, calculated values of attributes that are based on spatial data and prepared maps. We used Microsoft Visio to organize and display data in the form of advanced diagrams.

3.2 Study area

The system was developed and validated on data from the Natura 2000 site Ljubljansko barje (identification no. SI5000014 and SI3000271) (Figure 1). Ljubljansko barje is an agriculture landscape with the largest complex of wet grasslands in Slovenia. Its high biodiversity results from the mosaic of different habitats with high nature conservation value, such as lowland hay meadows with leper lilies (*Fritillaria meleagris*), orchids (*Orchidaceae*) and marsh gladiolus (*Gladiolus palustris*), and long narrow lines (over 100 km) of drainage ditches and hedgerows called "mejice" (45).

Characteristic are also scrubs and small standing water bodies, fragments of raised bog forest with red pine and birch, some small alnus and oak hornbeam stands, and Illyrian *Fagus sylvatica* forests predominantly on solitary confinement. Besides being designated as the Natura 2000 site, the study area also has other nature conservation statuses, namely the Ljubljana Marsh Nature Park, and an Ecologically Important Area of Ljubljansko barje (38).

3.3 Case study

Our case study was the Škofljica bypass project as planned in the National Spatial Plan (39). Its negative impact was primarily assessed in the corresponding Appropriate Assessment (AA) (29). The Škofljica bypass project is planned as a two-lane road with level crossings. Two alternatives of the bypass were assessed in the AA, namely the alternative 2a and the alternative OC. The length

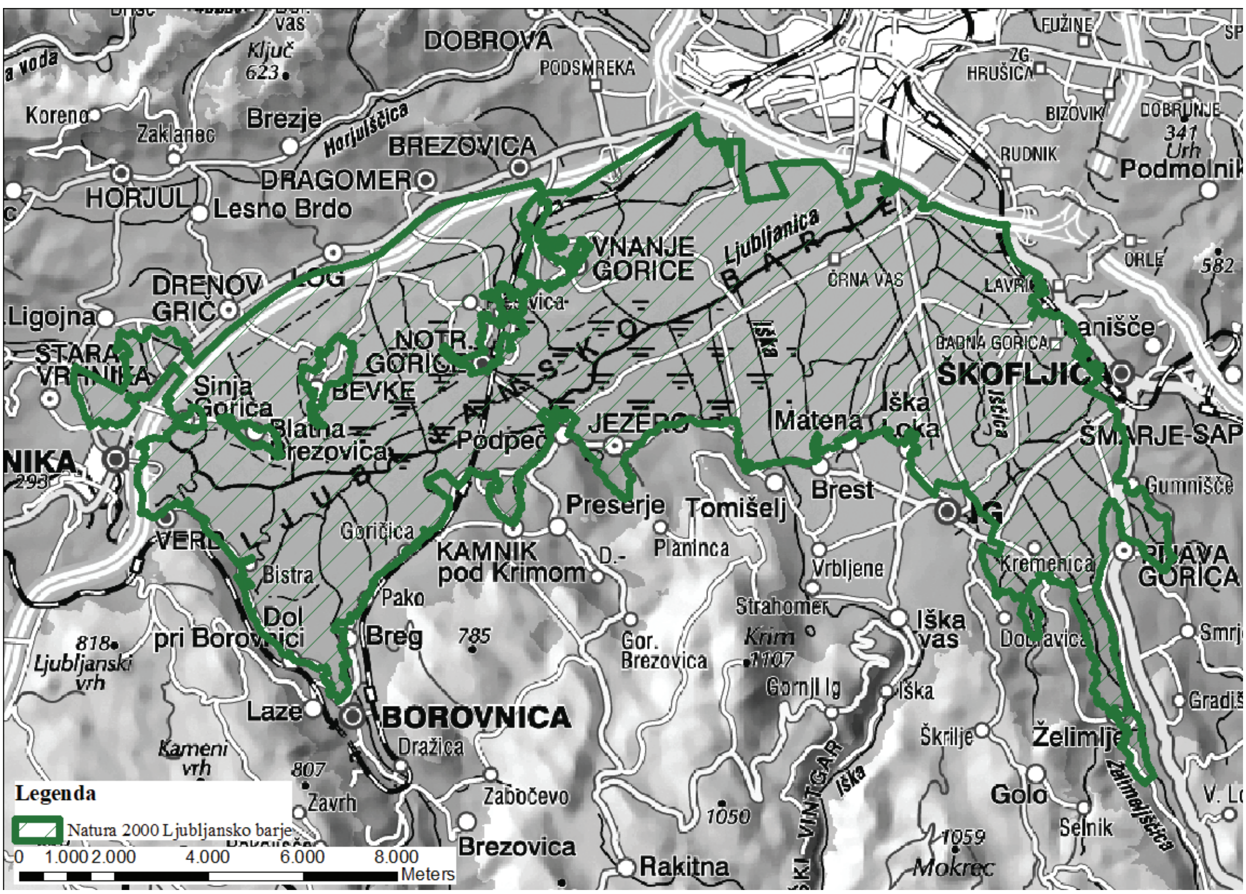

Figure 1: *Study area of the Natura 2000 site Ljubljansko barje in green.*

of the alternative 2a is 5421 m, while the length of the alternative OC is 5248 m (Figure 2) (29).

The AA was prepared by using the legally foreseen method. It showed that it is necessary for both alternatives to implement a CH for the False ringlet butterfly (*Coenonympha oedippus*) and a few bird species, namely the Northern lapwing (*Vanellus vanellus*), the Common quail (*Coturnix coturnix*), the Corncrake (*Crex crex*), the Whinchat (*Saxicola rubetra*), and the Eurasian scops owl (*Otus scops*). The CH was determined for both alternatives. The CH in the size of 369 ha must be implemented in the case that alternative 2a is chosen as the most appropriate alternative of the bypass. If the alternative OC is chosen as the most suitable alternative of the bypass to be build in the field, the CH in the size of 216 ha has to be implemented. The AA proposed to locate the CH in the predominantly arable areas that would have to be transformed into extensive grassland (29).

It was estimated that the implementation of CH is not technically very demanding and that the risk multiplier of 1.4 should be used. The CH would need to be fully functional before the start of construction (29).

According to AA, the CH is foreseen in three potential locations, all of which are placed within the same Natura 2000 site (Figure 2). The locations of CH were selected on the basis of the guidelines issued by the Institute of the Republic of Slovenia for Nature Conservation and the Slovenian Ministry of agriculture. The sizes of proposed areas are 180.66 ha for CH1, 143.66 ha for CH2, and 177.75 ha for CH3. The CH (369 ha for the alternative 2a or 216 ha for for the alternative OC) has to be established within 585 ha of the potential locations (29).

3.4 Model species

For our research, we selected the Whinchat (*Saxicola rubetra*) as our case study model species. The Whinchat is a migratory bird which dominant habitats are meadows. It nests on highly structured extensive meadows, especially fast-growing meadows with tall herb fringe communities (e.g. 6410 Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*); 6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels; 6510 Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)). It avoids large areas with dense scrubs, forests, intensive meadows, and pastures (40). It is threatened by early mowing (41). The Whinchat is regionally widespread in Slovenia (42), but its population has halved over the last decade (43). It is included on the Slovenian Red List and classified as an endangered species (E) (44).

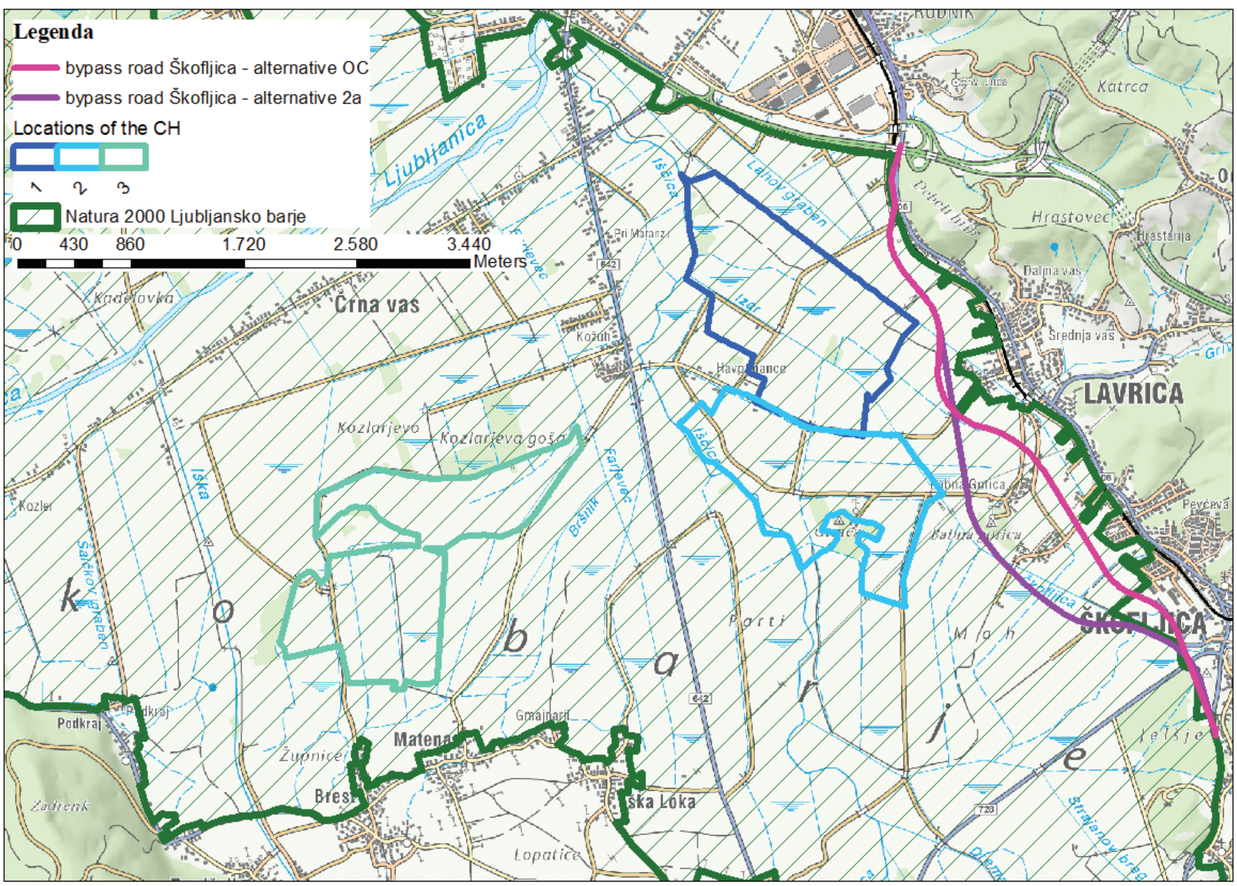

Figure 2: *Alternatives of the Škofljica bypass road project and the locations of the compensation habitat*

The Whinchat was a common breeder at the Ljubljansko barje in the period from 1990 to 2000 when its breeding population size was estimated to range between 1900 and 2300 pairs (40). This represented approximately 15 % of the Slovenian population at the time. The suitability and quality of the site for the conservation of the Whinchat was classified as good (45).

We used data from the Ornithological atlas of birds of Ljubljansko barje (40) to estimate the current abundance of breeding pairs of the model species in its habitat that will be lost by the implementation of the bypass road plan and in the proposed locations of CH. Since data in the ornithological atlas is available for 1 by 1 km grid cells, the abundance of model species in the areas of proposed CH was estimated by overlapping and interpolation of data from the grid cells to selected polygones of CH (40).

We assessed the importance of the spatial plan area and the areas of CH for the Whinchat by comparing the data on the breeding density on those areas with average density of the species on the Ljubljansko barje (37). If the density on the assessed study area was up to two times smaller as the average on the Ljubljansko barje, we estimated that the habitat quality and the population size of the assessed area were not optimal. On the contrary, we estimated that both the area and the population size were optimal for the species. The whole assessed area was treated equaly in the sense of habitat sutiability as locations and sizes of the actual nesting territories of birds vary slightly from year to year, so accurate mapping is not appropriate at this spatial level.

We estimated the difficulty of the habitat restoration/creation of the CH (Module I) and the time needed to ensure the same ecological function in the CH as it was in the habitat lost (Module III) by using the adapted British DEFRA method (15).

RESULTS

In order to achieve the aim of our research, we have built a new multi-level system for planning compensatory habitats. The system is based on a three-modules built with multi-attribute decision model (hereinafter referred to as a three-modular model).

4.1 Conceptual model

The conceptual model of the new multi-level system for planning CH is shown in Figure 3.

In Module I, we assess the impact that the implementation of the spatial plan could have on the model species. The level of the impact is based on four qualitative attributes (Figure 3 and 4). The first attribute (DSS) describes the distribution of the model species in Slovenia. It shows the spatial presence of the model species on the territory of the country regardless of the considered spatial plan. This attribute indicates the potential threat to the species (e.g. smaller areas with the presence of the model species indicate higher level of its threat). The second attribute (SPS) brings information about the stability of population at the level of Slovenia regardless to the spatial plan. The third attribute (CSP) gives an estimation about the change of the population size of model species due to the implementation of the spatial plan. The fourth attribute (DRC) indicates the difficulty of restoring lost habitats or creat-

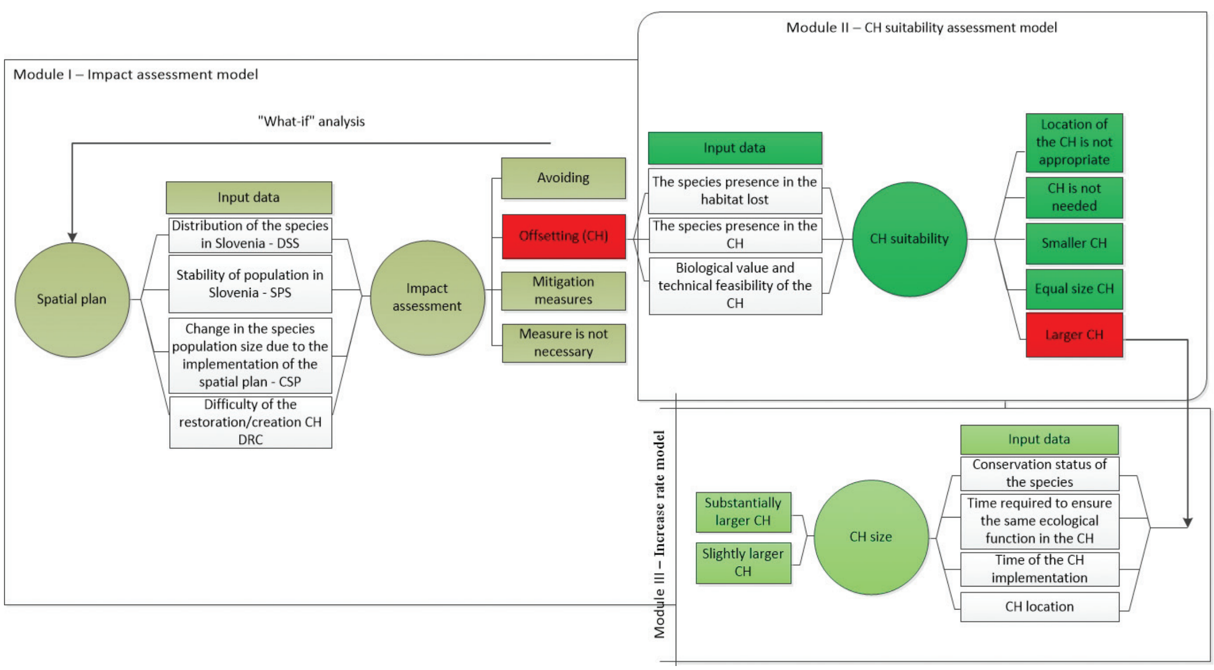

Figure 3: *Conceptual model of the three-modular system for planning compensatory habitats*

ing a CH. The qualitative values of the attributes from the Module I are given in Figure 4.

The impact of the assessed spatial plan (Module I) is described by four levels: "avoiding" (i.e. it is not recommended to implement the proposed spatial plan due to the high negative impact on the biodiversity even if the CH is implemented); "offsetting (CH)" (i.e. the impact is medium and it could be compensated with a CH); "mitigation measures" (i.e. the impact is low and can be mitigated with the on-site implementation of habitat modification measures); and "no mitigation measures" (i.e. there is no negative impacts of the proposed spatial plan on the model species). The more the species is endangered at national level (assessed by attributes DSS and SPS) and the greater the long-term negative impact of the proposed spatial plan (assessed by attributes CSP and DRC), the more restrictive is the result of Module I. For example, if the spatial plan has a major impact on a highly endangered model species, the Module I recommends avoiding the implementation of the spatial plan. If the plan's impact is assessed as low and the model species is slightly endangered, the Module I recommends the implementation of the on-site mitigation measures. In case that the output from the Module I is medium level of the impact, then the implementation of a CH is necessary, and its relative size is determined by Modules II and III.

Module II is structured from three attributes (Figure 3 and 5). The first attribute provides information about the presence and abundance of the model species in the habitats which would be lost by the implementation of the spatial plan. The second attribute describes the baseline presence and abundance of the model species in the areas where the CH could be created. The third attribute describes the biological significance and technical feasibility of the area of proposed CH. If the ecological conditions of proposed CH are similar to the area of habitat that would be lost due to the implementation of spatial plan, its biological significance is higher and the construction of a CH is technically more feasible. The contributions of all three attributes to the determination of the CH's relative size are equivalent. The scales of attributes' qualitative values from Module II are shown in Figure 5. The output from the Module II can take one of the five values, namely a smaller or a larger CH compared to the size of the lost habitat; a CH of a size equal to the lost habitat; the location of the CH is not appropriate; and the CH is not needed. If the population size of the species in the lost habitat is optimal, the Module II gives a more restrictive recommendation (e.g. equal or larger size of the CH compared to the area of the lost habitat). If the population size of the model species is optimal in the area where we plan to create the CH, the output from the Module II will propose that such location is not suitable for the CH, since its carrying capacity for model species is achieved and it would be difficult to increase it further for the number of individuals that would be expeled from the area of the implementation of the spatial plan.

If the output from the Module II shows that the CH must be relatively larger according to the size of the lost habitat, the rate of increase of the CH area is further determined by the Module III. Module III is based on four qualitative attributes, namely the conservation status of the species; the time required to provide the same ecological functions in the CH as that of a habitat lost; the time needed for the implementation of the CH; and the CH location according to whether the CH is provided in or outside the Natura 2000 site concerned (Figure 3 and 6). The Module III provides three output recommendations: a slightly larger CH, a substantially larger CH than the size of the habitat lost due to the implementation of spatial plan, and the proposed CH is not feasible. Slightly larger means an area of a CH that is between 1 to 2 times larger than the area of the habitat lost, while substantially larger means a CH more than two times larger that the habitat lost. The CH is not feasible e.g. in case where the required time to develop the same ecological functions in the CH as that of the habitat lost is high. The result of Module III is most restrictive if the compensation of significant impacts is needed for the Natura 2000 priority species and if it would take a long time for the CH to achieve its fully functionality. The restriction also increases with the distance of the CH location from the location of the habitat lost and when there is a time delay between the loss of the habitat and the establishment of a fully functional CH.

4.2 The qualitative multi-attribute decision models

By using the DEXi modelling tool (37), we transformed the Modules I, II and III from the conceptual model into three qualitative multi-attribute decision models. First, we structured the initial attributes from each

Attribute	Scale
Impact assessment model	Avoiding; Offsetting (CH); Mitigation measures; ***Measure not necessary***
├**Species endangerement**	High; Medium; Low; ***No***
│ ├Distribution of the species in SLO	Locally; Locally more locations; Regional; ***Entire country***
│ └Stability of population in SLO	Rapidly declining; Medium declining; Slowly declining; ***Stable or increasing***
└**Long-term impact of the spatial plan**	High; Medium; Low; ***No***
├Change in the population size due to the plan	High; Medium; Low; ***No***
└Difficulty of the CH restoration/creation	Impossible; High; Medium; ***Low***

Figure 4: *Structure of the model for assessing the impact of spatial plan on selected model species (Impact assessment model/Module I). Colours of the attributes' values correspond to the quality level (e.g. red – bad, black – neutral, green – good).*

Attribute	Scale
└CH suitability assessment model	Larger CH - go to Module III; CH not needed; CH location not appropriate; Equal size CH; Smaller CH
├Population size in the habitat lost	Species not present or individual specimen only; Non-optimal; Optimal
├Population size in the CH	Species not present or individual specimen only; Non-optimal; Optimal
└Biological value and technical feasibility of the CH	Conditions non-comparable; Conditions partly comparable; Conditions comparable

Figure 5: *Structure of the model for assessing the suitability and relative size of compensatory habitat (Compensation habitat assessment model/ Module II). Colours of the attributes' values correspond to the quality level (e.g. red – bad, black – neutral, green – good).*

Attribute	Scale
└Increase rate model	Substantially larger CH; CH not feasible; Slightly larger CH
├Conservation status of the species	Priority N2k and/or endangered; N2k species and/or vulnerable; Least concern, data deficient or not evaluated
├Time required to ensure the same ecological function in the CH	High; Medium; Short
├Time of the CH implementation	After the plan; Before the plan
└CH location	Outside N2k concerned, in different topographical unit; Outside N2k concerned, in common topographical unit; Within N2k concerned

Figure 6: *Structure of the model for assessing the rate of increase of the compensatory habitat area (Increase rate model/Module III). Colours of the attributes' values correspond to the quality level (e.g. red – bad, black – neutral, green – good).*

module into hierarchical trees by introducing additional aggregated attributes and defined their qualitative value scales. To integrate lower level attributes into parent attributes, we used utility tables which contain integration rules for all combinations of values of integrated attributes into a parent attribute. The structures of decision models and the qualitative values of their attributes (both initial and integrated) are presented in Figures 4, 5 and 6.

Table 1: *The values of the input data for an individual model. A value "/" means that there was no input data.*

Models	Attributes		Values of the input data	
			Alternative 2a	Alternative OC
I	The distribution of the Whinchat in Slovenia		Regional	Regional
	The stability of Whinchat population in Slovenia		Rapidly declining	Rapidly declining
	The change in the Whinchat population size due to the implementation of the spatial plan in the Natura 2000 site concerned		Low	Low
	The difficulty of the habitat restoration/creation of the CH		Low	Low
II	The Whinchat population size in the habitat lost	CH1	Optimal	Non-optimal
		CH2	Optimal	Non-optimal
		CH3	Optimal	Non-optimal
	The Whinchat population size in the CH	CH1	Non-optimal	Non-optimal
		CH2	Optimal	Optimal
		CH3	Optimal	Optimal
	The biological value and technical feasibility of the CH	CH1	Partly comparable	Partly comparable
		CH2	Comparable	Comparable
		CH3	Comparable	Comparable
III	The conservation status of the Whinchat	CH1	Endangered (E)	Endangered (E)
		CH2	/	/
		CH3	/	/
	The time required to ensure the same ecological function in the CH as it was in the habitat lost	CH1	Low	Low
		CH2	/	/
		CH3	/	/
	The time of the CH implementation	CH1	Before	Before
		CH2	/	/
		CH3	/	/
	The CH location	CH1	Within the Natura 2000 site concerned	Within the Natura 2000 site concerned
		CH2	/	/
		CH3	/	/

Evaluation results

Attribute	Škofljica baypass 2a	Škofljica baypass OC
Measure	CH	CH
├**Risk - species endangerement**	Medium	Medium
├Distribution of the species in SLO	Regional	Regional
└Stability of population in SLO	Rapidly declining	Rapidly declining
└**Impact - long-term impact that the spatial plan**	Low	Low
├Change in the population size due to the plan	Low	Low
└Difficulty of the CH restoration/creation	*Low*	*Low*

Figure 7: *Results of the assessment in Module I/Impact assessment model*

4.3 Data

Data describing selected case study and model species were collected by using the methodology described in section Material and methods. To populate models with data, we discretised all data of initial attributes according to their selected qualitative values which are described in section 3.1 and 3.2. Values of input data for the model (Module I) for the assessment of impact of the bypass road plan (Figure 4) and for two models for assessment of suitability (Module II) and relative size (Module III) of CH (Figure 5, 6) are presented in Table 1.

4.4 Results of the assessment with the Multi-Level System for Planning Compensatory Habitats

The results of the assessment of the impact of spatial plan on selected model species (Module I) show that it is necessary to implement a CH for both alternatives of the bypass road (as denoted with "CH" in the top-level attribute Measure in Figure 7). The input data for the Impact assessment model and the values of the integrated attributes for both assessed alternatives are shown in Figure 7.

If the end users (e.g. investors) would not like to provide additional financial and organisational support for the establishment of the needed CH, they can use the Module I for a "what-if" analysis. This will help them to determine which components of the spatial plan need to be changed in order to have less significant impacts on the model species and properties of the habitats exposed to the impacts due to the implementation of spatial plan. In our case, the spatial plan should be changed in such a way that the value of the attribute SPS (Stability of population in Slovenia) would change from Rapid declining to Slowly declining and the output from the Module I would consequently change to Mitigation measures (i.e. the impact of the modified spatial plan is low and can be mitigated with the on-site implementation of habitat modification without the need for a CH). Since this attribute involved into Module I is not directly linked to the spatial plan, such change cannot be achieved by modifying this particular spatial plan because the attribute SPS describes conditions of the model species at the level of Slovenia. The "what-if" analysis thus showed that the significant impacts to the Whinchat and consequently the implementation of the CH could be avoided only if the investor would abandon the current location of the spatial plan and find another location.

Since the output from the Module I is a CH (i.e. the impact of the assessed spatial plan is medium, and it could be compensated with a CH), the suitability of proposed location where the CH could be developed and its relative size are further assessed by Module II and Module III. The results of Module II (Figures 8 and 9) show that the implementation of a CH in location CH1 would require larger area of CH compared to the area of the habitat that would be lost by the implementation of either alternative of the assessed spatial plan. This is due to the fact that the

Evaluation results

Attribute	CH1	CH2	CH3
└**Module II**	larger CH - go to Module III	CH location not appropriate	CH location not appropriate
├Species presence in the habitat lost	*Optimal*	*Optimal*	*Optimal*
├Species presence in the CH	Non-optimal	*Optimal*	*Optimal*
└Biological value and technical feasibility of the CH	Conditions partly comparable	*Conditions comparable*	*Conditions comparable*

Figure 8: *Results of the evaluation of the study case the Škofljica bypass road, the alternative 2a, in Module II/ Compensation habitat assessment model*

Evaluation results

Attribute	CH1	CH2	CH3
└**Module II**	larger CH - go to Module III	CH location not appropriate	CH location not appropriate
├Species presence in the habitat lost	Non-optimal	Non-optimal	Non-optimal
├Species presence in the CH	Non-optimal	*Optimal*	*Optimal*
└Biological value and technical feasibility of the CH	Conditions partly comparable	*Conditions comparable*	*Conditions comparable*

Figure 9: *Results of the evaluation of the study case the Škofljica bypass road, the alternative OC, in Module II/ Increase rate model*

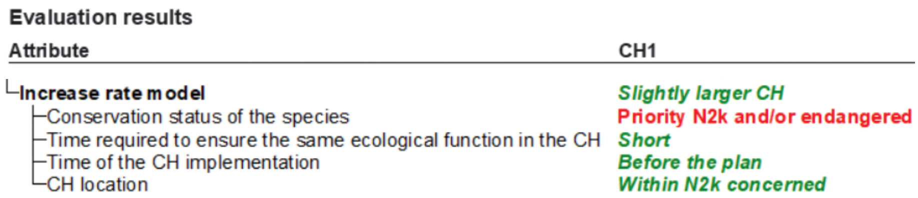

Figure 10: *Results of the evaluation of the study case the Škofljica bypass road, the alternatives 2a and OC, in Module III*

conditions at the location CH1 are only partly comparable to those at the habitat lost. Also, Module II shows that the locations CH2 and CH3 are not suitable for the implementation of the CH since the optimal size of the population of model species is already present at these two locations, meaning that the optimal carrying capacity for our model species has been achieved and it would be very difficult to increased it. For that reason, the investors would need to focus on the location of CH1 which has been recognised by Module II as a suitable solution for both alternatives of the spatial plan.

Because the output from the Module II (i.e. larger CH) is rather too general (i.e. larger CH), the output from the Module III gave us a more specific suggestion for how much the area of a new CH at the location of CH1 should be larger compared to the lost habitat. The results of the Module III (Figure 10) shows that a slightly larger CH (e.g. the risk multiplier takes values from 1.1 to 1.9) would already compensate for the significant negative impacts of the spatial plan with both alternatives as it was estimated that only short time would be needed to establish the same ecological function in the CH as the one at the habitat lost. In addition, the CH would be implemented before the realisation of the spatial plan and would be located within the same Natura 2000 site as the habitat lost.

DISCUSSION

We have developed a new multi-level system for planning CH based on a three-modular approach. With this system, we increased the objectivity and transparency of the assessment of the impact of spatial plans on model species and their habitat and of the process for determining CH. With this, we made a significant contribution to resolving the expert challenges that are, just as procedural and administrative ones, part of the AA processes. Also, the system described in this paper allows to easily search for the alternatives of spatial plans.

Module I addresses the hierarchy of avoidance-mitigation-offsetting, while Modules II and III respond in a nominative way to the question of the required value of the risk multiplier that determines the size of a CH.

The biggest challenge was choosing the most appropriate model structure and the most suitable attributes for the assessment. As Kolarič pointed out (32), there is a general lack of baseline data for biodiversity assessments in Slovenia, which we also encountered in our research. Usually, there is a lack of suitable data about model species or such data are outdated or not available at all. Fortunately, our case study at Ljubljansko barje was very well provided with the required data. Due to the good availability of data, we had no restrictions on what attributes to use for the construction of the models. In addition, good support by available data enabled us to perform the validation of the developed system before we used it for the assessment of the particular spatial plan described in this research work. According to Rayment et al (12), the use of consistent attributes described with good data is one of the key points that contributes to preventing the loss of biodiversity when implementing a CH. In addition, the chosen attributes support the simple and easy-to-use models by users involved in development of spatial plans and their realisation as well as by nature protection and conservation agencies. What is more, attributes for the assessment in this system were selected in a way that they ensure a transparent and more objective determination of the CH even if some baseline data are missing. In such cases, the domain expert provides a subjective assessment of the attributes. Moreover, data from the Natura 2000 Standard Data Form (SDF) can be used. However, this may influence the subjectivity and transparency of the decision-making process. Also, the efficiency of the system is in colerration with quality of available input data.

We can confirm the suggestion of Jereb et al (46) that the involvement of experts on the ecology of model species brings significant contribution to the development and validation of the new multi-level system for planning CH. Experts can provide an up-to-date information that is not publicly available yet, help with the correct interpretation of the input data and evaluate the modelling results from both scientific and empirical experiences. This is necessary and especially important for the validation of the models, particularly if there are not enough available data about the habitat properties and population size of the model species.

The methodology we used for the development of the models helped us to reduce the subjectivity in the decision-making process (e.g. with a decision whether the assessed spatial plan can be applied or not, what is the required size of a CH), but we did not manage to completely eliminate the subjectivity in the choice of attributes and to reduce the inaccuracy of the selected data. Regarding the latter, we used as much data as possible from published monitoring reports. When we used data provided by expert judgement, we reduced subjectivity by selecting experts with rich knowledge and experiences. However, since the amount of reliable data is always limited, the data needed for this kind of research work is most often a combination of monitoring reports and an expert judgement from experts on the model species.

Additional sources of subjectivity in multi attribute qualitative modelling is discretization of numeric data because the applied methodology is based on attributes with qualitative values. The largest challenge is the selection of discretization thresholds that are applied on numeric data of input attributes (e.g. the value for the CSP is high if it means more than 51 % decrease of population size.) These limit values in our system follow the quartile classes and the international conservation definitions (e.g. IUCN, the British DEFRA method). However, this potential source of unreliability of the model results can be minimised by data pre-processing and their expert interpretation. As we used this approach in our case, the described new system provides high level of objectivity of models' outputs.

Rather simple structure of the models that build our system is based on a short list of input data. The outputs, on the other hand, are very informative and useful for investors, developers of spatial plans and nature protection and conservation agencies (e.g. an applicability of the assessed spatial plan, a requirement for a CH). In addition, the developed system enables its flexible use at several levels of decision-making (e.g., suitability of spatial plan, what-if analysis, selection or the relative size of CH) and its application is time- and cost-efficient. As Bull et al pointed out (10), these are the key factors for the method to be used by investors and decision-makers involved in biodiversity offset studies.

With the described developed system, we assessed the impact of two alternatives of the Škofljica bypass road to the Whinchat. If we compare our results with results from the AA for the National Spatial Plan for the Škofljica Bypass (29), we see that they are similar to some degree. We have confirmed the results of the AA that a CH is necessary for both alternatives of the bypass road. Also, our results showed that CH has to be slightly larger (e.g. the risk multiplier takes values from 1.1 to 1.9) in order to compensate for the significant negative impacts of the spatial plan, what was also in concordance with the results of the AA, where the risk multiplier of 1.4 was recomended. However, the system we developed brings additional results that were not discovered in the AA study. Namely, we found that two out of three CH locations (CH 2 and CH 3) are not suitable for the compensation of the Whinchat habitat, because the optimal size of the Whinchat population is already present in these locations and the increase of their carrying capacities to a level necessary to harbour population from the destroyed habitats would not be possible. Our study is based on a structured and well-organized approach with a traceable and easily repeatable flexible multi-level system for planning CH. This means that different users could come to the same results. The approach used in the AA is generally not as transparent and clear as the one used in our system. Another advantage of our system is also that it includes the decision support for the user to more objectively estimate whether a selected area of CH is suitable for compensating the impacts of spatial plans in protected areas or not. As already pointed out by Bull et al (16), the selection of the most suitable method for calculating a CH is not easy and requires the knowledge of the conditions in both the habitat lost and in the CH as well as clearly determining the conditions that new CH has to meet.

In addition, the system also directs the evaluator to the more comprehensive thinking about and gathering information on the problem. This reduces the possibility of overlooking any important factors that could reduce the quality of the decisions they have to make.

An additional benefit of the new multi-level system for planning CH is also the possibility to search for different alternatives. The evaluator can perform a "what-if" analysis by changing the values of input data in order to test other possible scenarios that would generate different solutions. This was demonstrated with a "what-if" analysis in Module I where we proved that investors would need to find a new location for the bypass road where the model species is not present if they would not like to invest additional sources in the implementation of a CH. Therefore, the system enables end-users to evaluate different options and helps them to choose the most optimal alternative of the spatial plan.

The multi-attribute decision models, such as the one we developed for our multi-level system, are tools for supporting the decision-making process in challenging decision-making situations when a large number of factors have to be considered and/or when one of many alternatives has to be chosen. The computer-based tools can support building the decision model, assess alternatives, and offer a wide range of analyses to justify and document the decision, which contributes to a more quality decision and its implementation (46). However, such a tool cannot replace a decision-maker, who is still fully responsible for the choice of the final decision. The system only facilitates systematic and better-organized decision-making process and directs the decision-maker to use system thinking and comprehensive consideration of the problem at hand. This reduces the possibility that the end-user would overlook the key factors that influence the final decision.

This new multi-level system for planning CH is the first such tool in Slovenia that takes into account not only the area of the habitat lost but also habitat condition, habitat value and species abundance in the habitat lost and in the CH. Compared to the other existing methods (e.g. an expert judgement; simple models based solely on the surface area of a lost habitat), our system is clearly methodologically defined and potentially more accurate, but still easy to use. However, its reliability still depends on the quality of the input data. It is comparable with other modern international multi-attribute methods for determining the risk multiplier and the size of a CH, such as the British DEFRA method (15) and the Australian habitat hectare method (47).

This research provides a clear demonstration of the possible use of the new multi-level system for planning CH. The application of the system presented in this paper makes an exceptional contribution to the enhancement of the quality of the AA and contributes to preventing biodiversity losses already in the planning phase. At this stage, the system was tested on a bird model species, but it seems that it could be included in the process of the AA for species generally, as well as provide decision support about habitats. We tested the suitability and usefulness of the system for the Natura 2000 sites, but we believe that the system can also be used in other types of nature conservation areas as well as in unprotected areas with high natural value. In the near future, the applicability of our new multi-level system for planning CH on other species than birds is foreseen. Also, its use in the CH pilot areas, as it has been done in Great Britain (14), should be established to verify the conclusions on the field. This would provide us with additional useful empirical data only on which, according to Rayment et al. (12), should the risk multipliers be based.

Our findings strongly suggest that this system should significantly improve the CH designation procedure. However, other elements of the CH implementation procedure such as transformations of land use for CH, involvement of stakeholders, management, monitoring, costs, etc. (9, 18, 22, 23) can also strongly influence the success rate of the CH implementation and reaching the objective of no net loss of biodiversity. A future development of our system should take into account also those attributes to enhance its value of beeing a comprehensive tool in offsetting and habitat compensation.

REFERENCES

1. European Union 2011 The EU Biodiversity Strategy to 2020. Publications Office of the European Union, Luxembourg, p 28 http://ec.europa.eu/environment/nature/info/pubs/docs/brochures/2020%20Biod%20brochure%20final%20lowres.pdf
2. European Commission, Directorate-General for Environment 2015 Report from the Commission to the European Parliament and the Council: The Mid-Term Review of the EU Biodiversity Strategy to 2020. Brussels, p 19 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52015DC0478&from=EN
3. Uredba o posebnih varstvenih območjih (območjih Natura 2000) (Decree on special protection areas (Natura 2000 sites), Slovene), Ur. l. RS [The Official Journal of the Republic of Slovenia], no. 49/04, 110/04, 59/07, 43/08, 8/12, 33/13, 3/14, 21/16
4. Pravilnik o presoji sprejemljivosti vplivov izvedbe planov in posegov v naravo na varovana območja (Rules on the assessment of acceptability of impacts caused by the execution of plans and activities affecting nature in protected areas, Slovene), Ur. l. RS, no. 130/2004, 53/2006, 38/2010, 3/2011
5. Tucker G, Allen B; Conway M, Dickie I, Hart K, Rayment M, Schulp C; van Teeffelen A 2013 Policy Options for an EU No Net Loss Initiative: Report to the European Commission. Institute for European Environmental Policy, London, p 338 http://ec.europa.eu/environment/nature/biodiversity/nnl/pdf/Policy%20Options.pdf
6. European Commission 2012 Guidance document on Article 6(4) of the 'Habitats Directive' 92/43/EEC. Brussels, p 30 http://ec.europa.eu/environment/nature/natura2000/management/docs/art6/new_guidance_art6_4_en.pdf
7. Race M S, Fonseca M S 1996 Fixing Compensatory Mitigation: What Will it Take?. Ecological Applications 6 (1996): 94-101 https://doi.org/10.2307/2269556
8. Pastoroka R A, MacDonaldb A, Sampsona J R, Wilberc P, Yozzod D J, Titred J P 1997 An ecological decision framework for environmental restoration projects. Ecological Engineering 9 (1997): 89–107 https://doi.org/10.1016/S0925-8574(97)00036-0
9. King D M, Price E W 2004 Developing Defensible Wetland Mitigation Rations: A Companion to "The Five-Step Wetland Mitigation Ratio Calculator". King and Associates, Solomons Island, p 43 https://static1.squarespace.com/static/55c211c8e4b06ea5799e6c03/t/585acdb1e58c625687feb406/1482345906713/WetlandMitigationRatiosKingPrice2004.pdf
10. Bull J W, Suttle K B, Gordon A, Singh N J, Milner-Gulland E J 2013 Review biodiversity offsets in theory and practice. Fauna & Flora International, Oryx 47(3): 369–380 https://doi.org/10.1017/S003060531200172X
11. Conway M, Rayment M, White A, Berman S, Turbé A, Chenot B, Münchmeyer T, De Toni A, Johansson L, Mitsios A, Mudgal S 2013 Exploring potential demand for and supply of habitat banking in the EU and appropriate design elements for a habitat banking scheme. ICF International Company, London, p 158. http://ec.europa.eu/environment/enveco/taxation/pdf/Habitat_banking_Report.pdf
12. Rayment M, Haines R, McNeil D, Conway M, Tucker G, Underwood E 2014. Study on specific design elements of biodiversity offsets: Biodiversity metrics and mechanisms for securing long term conservation benefits. ICF Consulting Services, London, p 181 http://ec.europa.eu/environment/nature/biodiversity/nnl/pdf/Biodiversity%20offsets%20metrics%20and%20mechanisms.pdf
13. Robb J T 2002 Assessing wetland compensatory mitigation sites to aid in establishing mitigation ratios. Wetlands 2002: 435–440 https://doi.org/10.1672/0277-5212(2002)022[0435:AWCMST]2.0.CO;2
14. Bruggeman D J, Jones M L 2008 Should habitat trading be based on mitigation ratios derived from landscape indices? A model-based analysis of compensatory restoration options for the red-cockaded woodpecker. Environmental Management 42 (2008): 591–602 https://doi.org/10.1007/s00267-008-9179-2
15. Department for Environment, Food & Rural Affairs 2012 Biodiversity Offsetting Pilots - Technical Paper: the metric for the biodiversity offsetting pilot in England. England, p 27 https://www.gov.uk/government/collections/biodiversity-offsetting
16. Bull J W, Milner-Gulland E J, Suttle K B, Singh N J 2014 Comparing biodiversity offset calculation methods with a case study in Uzbekistan. Biological Conservation 178 (2014): 2–10 https://doi.org/10.1016/j.biocon.2014.07.006
17. Cuperus R, Cantersb K J, Udo de Haesb H A, Friedmanc D S 1999 Guidelines for ecological compensation associated with highways. Biological Conservation 90 (1999): 41-51 https://doi.org/10.1016/S0006-3207(99)00007-5
18. Quigley J T, Harper D J 2004 Effectiveness of Fish Habitat Compensation in Canada in Achieving No Net Loss. Oceans, Habitat and Enhancement Branch, Vancouver, p 16 http://www.ceaa.gc.ca/050/documents/48711/48711E.pdf

19. BenDor T, Stewart A 2011. Land use planning and social equity in North Carolina's compensatory wetland and stream mitigation programs. Environmental Management 47 (2011): 239–253 https://doi.org/10.1007/s00267-010-9594-z

20. Lange M, Cudmore-Vokey B C, Minns C K 2001. Habitat compensation case study analysis, Canadian Manuscript Report of Fisheries and Aquatic Sciences. Fisheries and Oceans Canada, Ontario: p 39 http://dsp-psd.pwgsc.gc.ca/collection_2007/dfo-mpo/Fs97-4-2576E.pdf

21. Rheinhardt R D, Brinson M M, Farley P M 1997 Applying wetland reference data to functional assessment, mitigation, and restoration. Wetlands 1997: 195-215 https://doi.org/10.1007/BF03161409

22. Moilanen A, Van Teeffelen A J A, Ben-Haim Y, Ferrier S 2008 How much compensation is enough? A framework for incorporating uncertainty and time discounting when calculating offset ratios for impacted habitat. Restoration Ecology 17, 4: 470–478 https://doi.org/10.1111/j.1526-100X.2008.00382.x

23. Oikos 2008 Utemeljitev predloga ureditve nadomestnega habitata na AC odseku Draženci– Gruškovje (Justification of the Proposal for the Offset at the Draženci–Gruškovje Highway Section, Slovene). Oikos, Domžale, p 35

24. Oikos 2009a Strokovne podlage za pripravo Državnega prostorskega načrta - Osnutek poročila o vplivih na okolje za daljnovod 2 x 400 kV Cirkovce–Pince (Expert Bases for the Preparation of the National Spatial Plan – a Draft of an Environmental Impact Assessment for the 2 x 400 kV Transmission Line Cirkovce–Pince, Slovene). Oikos, Domžale, p 316

25. Oikos 2009b Okoljsko poročilo za dopolnjen osnutek Izvedbenega prostorskega načrta Mestne občine Ljubljana (Environmental Impact Assessment for the Spatial Plan for the Municipality of Ljubljana, Slovene). Oikos, Domžale, p 186

26. Oikos 2010 Elaborat vzpostavitve nadomestnih habitatov za OPN Vrhnika (Study for Offsets Implementation for the Spatial Plan for the Municipality of Vrhnika, Slovene). Oikos, Domžale, p 55

27. Oikos 2013 Okoljsko poročilo (OP) za OPN občine Vrhnika in Dodatek za presojo sprejemljivosti vplivov izvedbe OPN Vrhnika na varovana območja (Environmental Impact Assessment and Appropriate Assessment for the Spatial Plan for the Municipality of Vrhnika, Slovene). Oikos, Kamnik, p 211

28. Poboljšaj K, Govedič M, Honigsfeld Adamič M, Jakopič M, Kotarac M, Kus Veenvliet J, Presetnik P, Rebeušek F, Slapnik R, Šalamun A, Trčak B 2008 Presoja sprejemljivosti vplivov izvedbe obvoznice Škofljica na varovana območja (Appropriate Assessment for the Spatial Plan for the Škofljica Bypass, Slovene). Center za kartografijo favne in flore, Miklavž na Dravskem polju, p 165

29. Gregorc T, Nekrep I, Šemrl M, Berce T, Hönigsfeld Adamič M 2012 Presoja sprejemljivosti vplivov plana na varovana območja v postopku priprave DPN za izgradnjo obvoznice Škofljica: dodatek k okoljskemu poročilu (Appropriate Assessment for the National Spatial Plan for the Škofljica Bypass, Slovene). Lutra, Ljubljana, p 169

30. Nekrep I, Gregorc T, Hönigsfeld Adamič M 2010 Inventarizacija ozkega vrtenca (*Vertigo angustior*) na delu Natura 2000 območja SCI Mirna kot podlaga za pripravo OPN občine Mokronog-Trebelno (Inventarization of *Vertigo angustior* in the Natura 2000 Area of SCI Mirna as the Basis for the Preparation of the Spatial Plan for the Municipality of Mokronog-Trebelno, Slovene). Lutra, Ljubljana, p 56

31. Kolarič Š 2010 Nadomestni habitati kot omilitveni ali izravnalni ukrep varstva narave pri posegih v prostor: diplomsko delo. (Offsets as Mitigation or Compensation Measures for Spatial Plans: B. Sc. Thesis, Slovene). Samozal, Ljubljana, p 145

32. Poboljšaj K 2011 Power point predstavitev: Nadomestni habitati v slovenskem sistemu varstva narave. V: Posvet Nadomestni habitati v varovanih območjih, 8. 12. 2011 (Power Point Presentation: Offsets in the Slovenian Nature Conservation System. In: The Consultion on Offsets in Protected Areas, 08. 12. 2011, Slovene). Center za kartografijo favne in flore, Miklavž na Dravskem polju, p 23 http://www.zrsvn.si/sl/informacija.asp?id_meta_type=73&id_informacija=769

33. Novak K 2014 Nadomestni habitati v krajinskem načrtovanju na primeru vplivnega območja HE Brežice in Mokrice: magistrsko delo (Offsets in Landscape Planning in the Case of the Influential Area of Hydropower Plants Brežice and Mokrice: M. Sc. Thesis). Samozal, Ljubljana, p 112

34. Gorenc N 2016 Pomen nadomestnih habitatov pri ohranjanju in vzdrževanju biotske pestrosti na primeru mokrišč: Magistrsko delo (Role of Offsets in Conservation and Maintaining of Biodiversity in the Case of Wetlands: M. Sc. Thesis). Samozal, Ljubljana, p 144

35. Figueira J, Greco S, Ehrgott M 2005. Multiple criteria decision analysis: state of the art surveys. Boston, Kluwer Academic Publishers: p 107 https://doi.org/10.1007/b100605 http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.9170&rep=rep1&type=pdf (10. 7. 2017)

36. Bohanec M 2006 Odločanje in modeli (The decision making process and the multi-attribute decision models). Ljubljana, DNFA – založništvo: p 312

37. Bohanec M 2015 DEXi: Program for Multi-Attribute Decision Making, User's Manual, Version 5.00. http://kt.ijs.si/MarkoBohanec/dexi.html (10. 7. 2017)

38. ZRSVN 2013 Nature Conservation Atlas https://www.naravovarstveni-atlas.si/web/?culture=en-US

39. Program priprave državnega lokacijskega načrta za izgradnjo obvoznice Škofljica (Programme for Drawing up a National Location Plan for Škofljica Bypass Road). Ur. l. RS, no. 74/2005

40. Tome D, Sovinc A, Trontelj P 2005 Ptice Ljubljanskega barja (Birds of the Ljubljansko barje, Slovene). Društvo za opazovanje in proučevanje ptic Slovenije, Ljubljana, p 417

41. Tome D 2007 Rast mladičev repaljščice Saxicola rubetra na Ljubljanskem barju (osrednja Slovenija) (Growth of the *Saxicola rubetra* 's Cubs at the Ljubljansko barje (Central Slovenia), Slovene). Acrocephalus, 28, 2007, (133): 51–55

42. DOPPS 2012 – 2018 Novi ornitološki atlas gnezdilk Slovenije (New Ornithological Atlas of Nesters of Slovenia: online data system, Slovene) http://atlas.ptice.si/atlas/index.php?r=user/login

43. Tome D, Denac D 2009 Individualno barvno obročkanje kot metoda v varstveni biologiji – preliminarni rezultati študije repaljščice (*Saxicola rubetra*) na Ljubljanskem barju (Individual color ringing as a method in conservation biology – preliminary results of the study of the Whinchat (*Saxicola rubetra*) at the Ljubljansko barje). Nacionalni inštitut za biologijo, Ljubljana, p 8 https://www.dlib.si/stream/URN:NBN:SI:DOC-9B6RTGMS/bd48dd20-6ed6-49cc-940e-87e61d09502f/PDF (30. 7. 2017)

44. Pravilnik o uvrstitvi ogroženih rastlinskih in živalskih vrst v rdeči seznam (Rules on the inclusion of endangered plant and animal species in the Red List, Slovene) Ur. l. RS, no. 82/2002, 42/2010

45. EEA 2017 Natura 2000 - Standard Data Form Ljubljansko barje., European Environment Agency, Brussels, p 7 http://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=SI5000014

46. Jereb E, Bohanec M, Rajkovič V 2003. Dexi: računalniški program za večparametrsko odločanje: uporabniški priročnik (Dexi: A Program for Multi-Attribute Decision Making: user manula, Slovene). Moderna organizacija, Maribor, p 91

47. Department of Environment, Land, Water and Planning 2017 Guidelines for the removal, destructi on or lopping of native vegetation https://www.environment.vic.gov.au/__data/assets/pdf_file/0021/91146/Guidelines-for-the-removal,-destruction-or-lopping-of-native-vegetation,-2017.pdf