School of Doctoral Studies in Environmental Engineering

Habitat potential and connectivity assessment to support land-use planning: a case study in an Alpine valley floor

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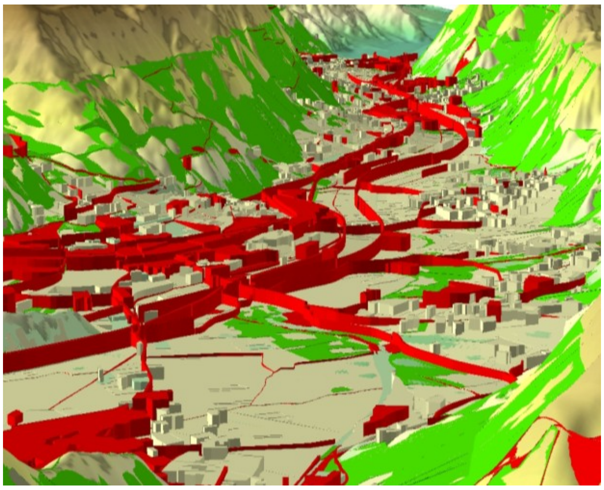

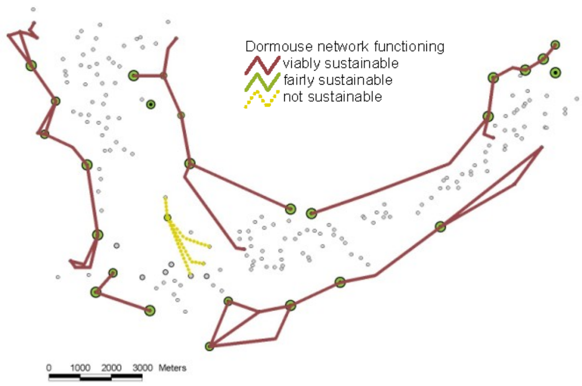

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The ants of the *Formica Rufa* family of Italian Alps destroy 14 million kg of pests every year
and the insectivorous birds in Italy destroy 300 million kg of such pests.

from DISSESTO ECOLOGICO FAME E INSICUREZZA NEL MONDO by Mario Pavan, 1987

(...) strange experience whereby we (and perhaps other mammals) are sometimes conscious of the products of our perception but unconscious of the greater part of the processes.
(...) All these things interconnect each others, and thus they form a network that, somehow could be named Mandala, in oriental language, but I feel at ease with the word Ecology.

from MIND AND NATURE by Gregory Bateson, 1979

Acknowledgements

The PhD research required years at a computer, tons of papers, piles of books and notes, but luckily not only that. Important aspects of “doing a PhD” were the interacting, sharing and discussing ideas with a lot of people, who had motivated, inspired and supported my work.

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This thesis could be finished also because of the particular patient and impatient support of Maìra. Thanks for being impatient when I needed it (missing the priorities), and patient in my down moments (losing the same priorities). You have listened about my thesis so much (and understood so well) that you are able to abridge and illustrate it to non-academic people better than me! Now, ready for the next! ... willing to share with you all that’s coming.

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Chapter 1

Introduction

1.1. Biodiversity and land-use change: a growing conflict

Human-induced land-use changes are the main source of global environmental change, becoming central to the sustainable development debate (Foley et al. 2005; Jingan et al. 2005). Land-use changes occur at every spatio-temporal scale, changing the configuration and functioning of ecosystems. From the Earth system scale (considering e.g. ecosystem processes and function, as for the climate system) to the local scale (considering e.g. habitat loss in rare small ecosystems) all spatial scales are undergoing important changes (Jingan et al. 2005).

In Europe, the Corine Land Cover database shows significant recent changes in land use 2000 (EIONET 2008). During the ten year period 1990–2000, at least 2.8% of Europe's land was subject to a change in use, including a significant increase in urban areas (with a range of 0.3-10.0% among Member States). In this decade the growth of urban areas and associated infrastructures throughout Europe consumed more than 8,000 km^2, equivalent to complete coverage of the entire territory of the state of Luxembourg (EEA Report No 10/2006). In the same decade, the urbanization in Italy has sealed 839 km^2 of rural areas (16 % of former rural areas), with a daily consumption of land of 23.1 ha. This makes Italy the second "land consumer" in Europe (Pileri 2007).

Artificial land-cover modifications, such as drainage, agriculture intensification, road construction and settlement development, reduce the suitable habitat areas and fragments remaining populations of wildlife species (Pellet et al. 2004). Habitat deterioration, fragmentation, isolation and loss caused by land-use changes, entail the most serious threats to biodiversity (Bennett 1999; Hanski and Ovaskainen 2003; Lindenmayer and Fischer 2006; Saunders et al. 1991; Turner 1996). Today, habitat loss and fragmentation is foremost cause of species extinction (Fahrig 2003).

On the other hand, globally, the most of biodiversity co-occurs in areas with human disturbance, in the low altitude belts (Jingan et al. 2005). This is due to two reasons: often the higher biodiversity areas provide larger resources for human activities, in other cases the historically human-dominated landscapes provide heterogeneous habitats to which many species adapted. This has been involving a strong and increasing (Aeschimann et al. 2004) competition between land uses. The available areas are in demand both for the biodiversity and ecosystem services and for space or resources for human activities (e.g. agriculture, settlements and infrastructures) they provide.

1.2. Alpine valley floors: a particular context of the conflict

Especially in the Alps, the most of biodiversity is linked to artificial or semi-natural environments and to traditional land-use (Chemini and Rizolli 2003). Alps are among the most important regions for biological diversity in the world (IUCN, 1992). This region provides the most important reservoir of biodiversity for Europe, with more than 4500 species of plants and 30,000 species of animals. The Council of Europe, within Directive 92/43/CE, has defined the "Alpine Biogeographic region" (Roekaerts 2002), among others, to establish specific policies for the conservation of habitats and of wildlife species.

Even though a significant part of the Alpine region (18%) is included in natural reserves (under different categories), the protected areas are often located at high elevation. Because of this, these areas do not cover the whole variability of Alpine biodiversity (Bätzing 2003; Sergio and Pedrini 2007). Again, most of the biodiversity resides in low-elevation areas (Chemini and Rizolli 2003; Sergio and Pedrini 2007). Many species depends on habitats provided by valley floors, and some threatened species find here the unique area of occurrence (Stoch 2000).

At the same time, Alpine valley floors have a particular morphology that exacerbates human-induced habitat fragmentation and the conflicts between the different land uses. Urbanization, with development of infrastructures and settlements, impacts ecosystems by a considerable splitting effect on the space. "Agriculture both creates pressures on the environment and plays an important role in maintaining many cultural landscapes and semi-natural habitats" (Tappeiner et al. 2003). The remnant natural or semi-natural areas are scattered and generally lacking in continuity. The ecosystems of the Alpine valley floor are undergoing increasing pressures. For these reasons, these fragile environments require particular attention in the assessments of ecological consequences of plans and projects.

1.3. Biodiversity conservation: preserving habitats and their relations

Environmentally sustainable development implies that landscapes are changed and exploited in a way that ensures they will remain in a healthy state and their services will be available for use by following generations (Leitao and Ahern 2002; Potschin and Haines-Young 2006). The spatial dimension of sustainability entails preserving and managing processes and relations between different land uses, ecosystems and biotopes at different scales. In other words, spatial planning should maintain the landscape ecological functioning in order to guarantee the habitat availability for as many species as possible (Opdam and van den Brink 2007).

Biodiversity provides resources, such as genetic bank and essential ecosystem services to the human population, including nutrient cycling, climate and water regulation, food production and recreation (Naeem et al., 1999). Furthermore, biodiversity plays a role in the ecosystem processes like resistance, i.e. the ability to maintain an ecosystem function despite perturbations and resilience, i.e. the ability to recover to normal function levels after disturbance (Peterson et al. 1998).

The biodiversity conservation is acknowledged as a global issue at international level, since the Convention on Biological Diversity (CBD), output of the UNCED (Rio) summit of June 1992. In Europe, the issue has been recently focused with "EU Strategy on Biodiversity" and "Understanding Biodiversity", the research agenda prepared by the European Working Group on Research and Biodiversity (Catizzone, 1998). Many thematic policies, established by European Union, deal with biodiversity conservation, such as:

- A sustainable Europe for a better world: A European Union Strategy for Sustainable Development COM (2001) 264
- Thematic Strategy on sustainable use of pesticide (2002) 349
- Thematic Strategy on the urban environment (2005) 718
- Thematic Strategy on the sustainable use of natural resources (2005) 670
- Thematic Strategy for soil pollution (2005) 176
- Halting the loss of biodiversity by 2010 and beyond: sustaining ecosystems services for human well-being (2006) 216.
- Thematic Strategy on Soil Protection, (2006) 231

The recent European "Biodiversity Action Plan" (2006) calls "for measures to support the sufficiency, coherence, connectivity and resilience of the broader protected area network and the need for biodiversity adaptation measures in response to climate change". In order to implement the CBD principles and international engagements, the EU created also a series of legal instruments.

In particular, "Habitats" Directive 92/43/EC and "Birds" Directive 79/409/EC provide the main legislation references claiming biodiversity conservation in the European Union. These directives concern conservation of natural habitats and of wild fauna and flora species. Article 3 of the Birds Directive (79/409/EC) stated that habitat conservation and restoration measures have to be taken "inside and outside protected areas". Article 10 of Habitats Directive (92/43/EC) suggests that conservation of landscape features for supporting the coherence of the Natura 2000 network requires adequate land-use planning tools. Hence, the attention, i.e. the measures and management, should not be focused only on protected areas but also "elsewhere where necessary", going beyond the approach of conservation based on nature reserves. Thus, the key issue is preserving the ecological spatial relations between remnant natural areas, by preserving the connectivity as well as the ecological functioning of landscapes.

Article 3 of the Birds directive:
“Member States shall take the requisite measures to preserve, maintain or re-establish a sufficient diversity and area of habitats for all the species […] in accordance with the ecological needs of habitats inside and outside the protected zones.”

Article 10 of the Habitats directive:
‘Member States shall endeavour, where they consider it necessary, in their land-use planning and development policies and, in particular, with a view to improving the ecological coherence of the Natura 2000 network, [...] by virtue of their linear and continuous structure (such as rivers with their banks or the traditional systems for marking field boundaries) or their function as stepping stones (such as ponds or small woods), are essential for the migration, dispersal and genetic exchange of wild species.’

Fig.1.1 Articles from Habitat and Birds directives, a starting point of the present study.

1.4. Assessment of land-use change consequences on biodiversity

In order to prevent biodiversity loss is pivotal understanding ecological consequences of project and plan proposals. This would require a detailed monitoring of environmental effects of any territorial development, e.g. during the whole carrying out of a plan, without overlooking even the realization of a single project.

Settlement and infrastructure developments often progress by single constructions, sometimes even in spite of plans or programs. This may cause the so-called “erosion” of biodiversity (Miller 2005), especially in human-dominated landscapes, where habitats are already fragmented and at risk of further fragmentation as a result of ongoing developments and land-use changes (Kettunen et al. 2007).

Negative effects on biodiversity may emerge later as result of cumulative effects, named “nibbling loss” due to a sequence of apparently “not meaningful” impacts (Hegmann et al. 1999). This is the case in which household construction projects are assessed individually. The assessment of a single project might easily report “trivial” impact on the ecosystems (e.g. related to the value of some hundred square metres of wood). Besides, pressures on natural areas come not only from a new land-use but equally from cumulative effects of land-uses in the past and also from the combined impacts of several small sources that can have equally severe effects on quality of water, soil and air (EEA 2006). Since a rapidly increasing household sprawl is acknowledged at global scale and considered as serious challenge to biodiversity (Liu et al. 2003), nibbling loss appears to be an important issue.

Two commonly used tools intend to avoid adverse environmental effects that might be associated with proposed developments or new activities are Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). The common ground of both tools is the purpose of fostering the environmental sustainability.

However, several authors have highlighted shortcomings of EIA and SEA in ecological impact assessment (e.g. Geneletti 2002; Mandelik et al. 2005; Treweek 1999). One of the main constraints in SEA and EIA applications is the lack of adequate information on local

biodiversity and on ecological processes potentially affected by project proposals (Mandelik et al. 2005). Even though the increasing literature has been developing guidelines to improve the quality of environmental assessments (Beanlands and Duinker 1983; Slootweg 2005; Slootweg and Kolhoff 2003), these guidelines seem not to be fulfilled. In practice, biodiversity impact assessment is seldom considered (Gontier et al. 2006). Generally, the assessment of ecological impacts due to land-use changes fails, particularly in identifying thresholds of disruptive impacts on processes (Vos 2001).
On the other hand, the information available for planners offers limited support to the assessments, being focused and specialized for protected areas and consisting in description of features (e.g. species inventories) rather than an assessment on their value (Geneletti 2008). Since the protected areas may not cover the whole biodiversity in a region (see the Alpine region) the ecological importance of all areas in human-dominated landscapes should be systematically investigated. Moreover, land-use planning, as well as EIA/SEA applications, should be based on assessment on the overall biodiversity asset of the territory of concern; ecological effects cannot be evaluated if the assessment is confined to isolated parts of a landscape (Treweek 1996).
The assessment of land-use change consequences on biodiversity could be improved by incorporating tools and concepts from the field of landscape ecology, since preserving the landscape structure and its ecological functioning has been increasingly acknowlegded crucial for biodiversity conservation (e.g. Opdam et al. 2001; Opdam et al. 2003; Slootweg and Kolhoff 2003). In effect, research fields such as ecological modelling and landscape ecology have been contributing to the understanding of biodiversity functioning and organization with concepts and theories which are broadly used today. Such developments, in combination with ongoing achievements in geographic information systems (GIS), can provide new possibilities for qualitative and quantitative modelling (Gontier et al. 2006), compensating the generally weak predictive nature of the ecology field (Treweek 1996).
Anyhow, methods derived from landscape ecology for quantifying and predicting impacts of the landscape structure on biodiversity are still debated (e.g. Fahrig 2003; McGarigal and Cushman 2002). Many available indexes and tools, used in EIA applications, are lacking explicit relations with ecological processes (e.g. Opdam et al, 2002; Vos et al, 2001). Further development in environmental assessment tools and methods should focus on both *functional* and *structural* components of biodiversity, not only on *compositional* component (Noss 1990; Slootweg and Kolhoff 2003).

1.5. Objectives and outline of the thesis

The thesis was motivated by two issues, besides the ones above mentioned. The first came from the first period of my PhD grant, in which I developed of an expert-based decision support system for environmental impact assessment (Sistema Informativo della Sensibilità

Ambientale, SISA). The second raised from the goals defined by the above-cited European Directives: “supporting the preservation, maintenance and re-establishment of biotopes and habitat (…) inside and outside the protected zones”.

The research was meant to develop a methodology providing operational indications for spatial planning and environmental assessment, fostering conservation or restoration of the landscape ecological functioning, in order to support the development of a sustainable landscapes. A related and secondary objective was to provide a representation of landscape ecological processes (then the possible impacts on them) easy to understand and to be communicated to decision makers and other stakeholders. In other words, the ultimate goal, in accordance with issues currently in progress (Opdam et al. 2001), was to foster an operational link between the planning and landscape ecology.

The research focused on Alpine valley floors, since this is a particularly vulnerable context, requiring urgent attention and a dedicated approach. Nonetheless, the proposed methodology may be adapted to other contexts, as those human-dominated landscapes where functional connectivity plays a pivotal role in maintaining local biodiversity.

The main idea was to develop methodology for the assessment of habitat potentialand habitat connectivity, fulfilling two requirements (or sub-objectives). The assessments have to require as little data as possible, in order to provide indications even with poor environmental dataset available. The assessment outputs have to provide measurements explicitly referring to ecological processes, in order to improve understanding of ecological consequences of planning. Hence, the approach takes into account the species perspective of landscape to appraise possible species responses to ecosystem modifications.

In order to achieve these goals, specific objectives were pursued by the following steps:

I. Review shortcomings within literature and studies concerning spatial planning and environmental impact assessment.

II. Review the literature concerning landscape ecology and conservation biology, to depict the state of the art of theories and tools effective in supporting ecological impact assessment for spatial planning.

III. Development of a methodology for the assessment of habitat potentialand functional connectivity.

IV. Application on a study area, an Alpine valley floor, in order to test the methodology.

V. Application for a local plan, in order to verify the effectiveness in supporting spatial planning.

The outline of the thesis can be summarized as follows. Chapter 2 presents the key concepts related to sustainable landscapes, i.e. biodiversity, habitat, fragmentation, connectivity, emphasizing on operational issues such as indices and measurements. A review of uses of these concepts by main literature in the last decade is also presented. This chapter also mentions the previous project (SISA project) that motivated the present research. The conclusions addressed the development of the proposed methodology, providing indications based on the review. Chapter 3 presents the whole methodology, based on the assessment of habitat potentialand functional connectivity, within a hierarchical framework. In Chapter 4 the study area is presented, emphasizing the actual pressures on scattered natural and semi-natural areas. Chapter 5 contains the application of methodology on the study area, providing an assessment about the actual ecological landscape functioning. In Chapter 6 the previous results are shown in the application to a real case of environmental assessment for municipal urban planning. Finally, Chapter 7 presents conclusions of the study, summarizing limits and innovation aspects and suggesting elements for further research.

Chapter 2

Assessment of land-use change consequences on biodiversity: literature review

2.1. Introduction

This chapter aims at setting the framework of research, presenting specific literature reviews with different objectives. The first objective I intended to report operational definitions for key ecological issues for spatial planning, such as biodiversity, habitat loss, habitat fragmentation, and connectivity. Since many interpretations and definitions of same issue are applied within studies and applications, this requires explicitly setting clear references for assessment.
The second objective regarded two research fields, focusing on the use of ecological concepts. The first field concerns spatial planning and environmental assessment; the second field pertains landscape ecology and conservation biology. On the one hand, this review was meant to survey shortcomings of the EIA applications or related studies, in order to depict a starting point for the present research. On the other hand, this was meant to define the state of the art of the methodologies and tools that may support effectively spatial planning in maintaining the landscape functioning.
The chapter also presents a previous project for the same study area (Trento province), an expert-based support system for environmental assessment. The scope and the limitations of that support system have motivated the present research.
Concluding the chapter, approaches supposed to be most contributing to assessment of ecological consequences of plans and projects are briefly reported, in order to set the theoretical and operational framework for the proposed methodology.

2.2. A review of key ecological concepts for sustainable planning

Concepts such as “biodiversity”, “habitat”, “habitat fragmentation” and connectivity” are pivotal for a land use planning aware of possible ecological impacts. The following paragraph describes briefly these concepts, focusing on an operational perspective for spatial planning.
The term “habitat” is often used loosely as equivalent to “native vegetation” or other land cover type. The same branch of trees could be seen as patch, within a binary framework matrix-patch (Forman and Godron 1986) or as habitat area for a defined hollow-dependent species (e.g. a woodpecker). The term ‘habitat fragmentation’ is used as an umbrella term for many ecological processes, related to patterns of vegetation covers or to biotic responses that accompany alteration of landscapes by humans (Fahrig 2003; Lindenmayer and Fischer

2007). The habitat loss assessment within the two cases may be actually different. Lindenmayer and Fischer (2006) surveyed more than 2000 papers with keywords “habitat fragmentation” and “habitat loss”. These authors claim researchers and planners to specify whether the focus of an analysis is on land-cover patterns in a landscape (e.g. amount and configuration of vegetation) or on patterns of habitat suitable for a particular species (Lindenmayer and Fischer 2007).

2.2.1. Operational definitions of “biodiversity”

Over the last decades, the term “biodiversity” has come into widespread use. With the diffusion of the term different definitions or interpretations have been used. Definitions of biodiversity range in scope from “the number of different species occurring in some location…” (Schwarz et al. 1976 in DeLong 1996) to “…all of the diversity and variability in nature” (Spellerberg and Hardes 1992 in DeLong 1996). More than 85 different definitions are reviewed (DeLong 1996; Sarkar and Margules 2002; Takacs 1997). Many definitions of biodiversity fail to mention the processes, such as interspecific interactions, natural disturbances and nutrient cycles, which are crucial to maintaining biodiversity and integral part of it (Slootweg 2005).

According to UNEP (Global Biodiversity Assessment), “*biodiversity is defined as the total diversity and variability of living things and of the systems of which they are part. This covers the total range of variation in and variability among systems and organisms, at the bioregional, landscape, ecosystem and habitat levels, at the various organismal levels down to species, populations and individuals and at the level of population and genes. It also covers the complex sets of structural and functional relationships within and between these different levels of organisation, including human action and their origins and evolution in space and time.*”(Watson et al. 1995).

The ecosystem approach proposed within Convention on Biological Diversity (CBD, 2004) emphasizes processes, functions and interactions among organisms and their values for humans. The framework of the Millennium Assessment (MA, 2003) read biodiversity as providing ecosystem services, i.e. provisioning resources (e.g. food, water, fibber and fuel), cultural values (e.g. spiritual, aesthetic, recreation and education), regulating processes (e.g. climate regulation, water and disease) and biogeochemical cycles (e.g. primary production and soil formation) supporting human well-being. This interpretation emphasizes how biodiversity is used and valued by society.

To be in accordance with CBD and MA approaches, EIA and SEA should define all biodiversity components and their use for society and provide information how a project is going to change these ecosystem components or services. Anyhow, a definition of biodiversity that is altogether simple, comprehensive and fully operational (i.e., responsive to real-life management and regulatory questions) is unlikely to be found (Noss 1990).

According with Noss (1990), more useful than a definition would be a characterization of biodiversity that identifies the major components, at several levels of organization. In fact, the biodiversity encompasses multiple levels of biological organization.

Franklin et al. (in Noss 1990; 1988 in Slootweg 2005), recognized three primary attributes of ecosystems: *composition*, *structure* and *function*. These attributes determine and, in fact, constitutes the biodiversity of an area. *Composition* deals with the identity and variety of elements in a collection and includes species lists or measures of species diversity. *Structure* is the physical organization or pattern of a system, it ranges from habitat complexity measured within a community to the pattern of patches and other elements at a landscape scale. *Function* involves ecological and evolutionary processes, including gene flow, disturbances and nutrient cycling. Compositional, structural and functional components of biodiversity are like interconnected spheres, each encompassing multiple levels of organization. This conceptual framework may facilitate selection of indicators that represent the many aspects of biodiversity that warrant attention in environmental monitoring and assessment programs.

The assessments pursuing the biodiversity conservation should concern all three spheres: distribution of biodiversity components, their structures and functions sustaining it. Lower levels in hierarchy contain the details (e.g. the species individuals and abundances) of interest to conservationist and the mechanistic basis for many higher-order patterns. No single level of organization (e.g. gene, population, community) is self-contained, otherwise different levels of resolution are appropriate for different questions (Noss 1990).

Somehow, the growing concern over compositional diversity has not been accompanied by an adequate awareness of structural and functional diversity (Franklin 1988). In effect, as shown in the following paragraphs concerning the EIA/SEA application shortcomings, structural simplification of ecosystems and disruption of ecological processes are not fully acknowledged as being important impacts.

On the other hand ecological indicators need to capture the complexities of the ecosystem yet remain simple enough to be easily and routinely monitored. Ideally the suite indicators should represent key information about structure, function and composition of biodiversity (Dale and Beyeler 2001). The nested levels of the ecological hierarchy (Fig. 2.1) mean the complexity of biodiversity but they also suggest that knowledge of one part of a level may provide information relevant to another level of the system. Often it is easier to measure structural features that can convey information about the composition or function. As example, the size of the largest patch of a habitat often restricts the species or tropic level of animals that rely on minimal territory size (Lindenmayer et al. 2000b).

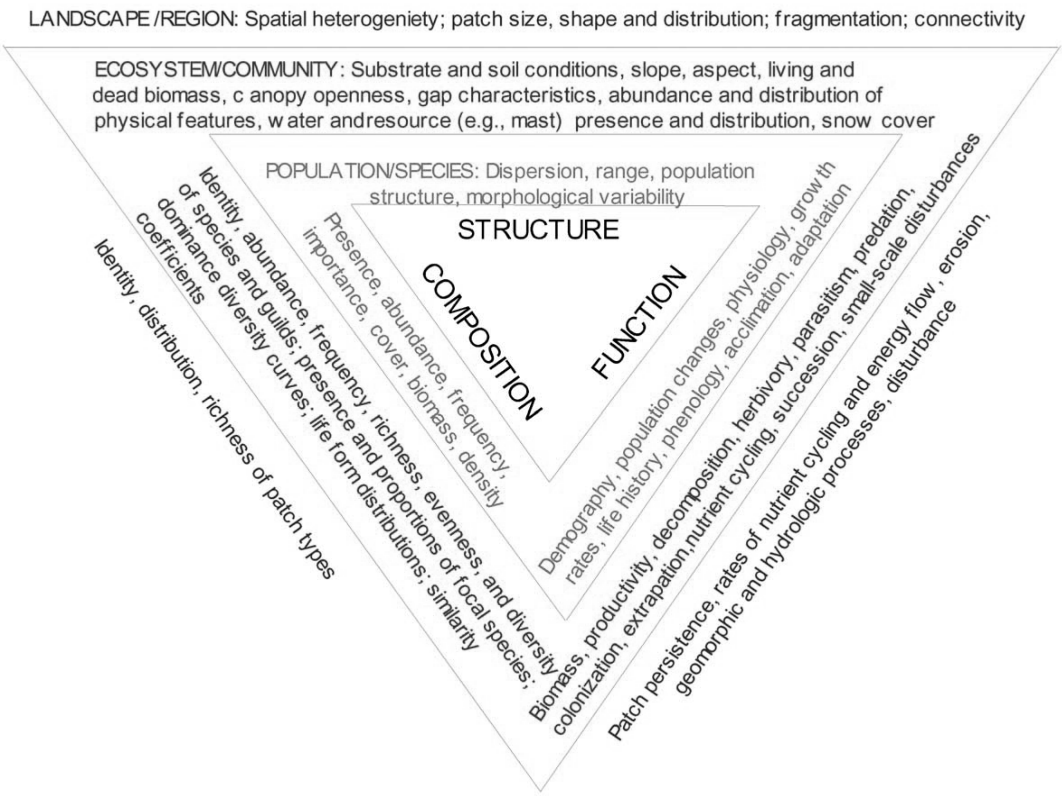


Fig. 2.1 The ecological hierarchy and possible related indicators (Dale and Beyeler 2001).

The species richness is often considered the basic indicator of biodiversity. Notwithstanding conservation biologists and planners too, now recognize the biodiversity issue as involving more than just species diversity or endangered species (e.g. Noss 1990), the species richness underlies many ecological models and conservation policies (e.g. Eiswerth and Haney 2001; Margules and Usher 1981; Rossi et al. 2008; Smith and Theberge 1986). Since Simpson Index (1949) and Shannon Index (1949; Whittaker 1965), today there are at least twenty-three indices (Giavelli et al. 1986) have been used in several kinds of environmental assessments.

In addition, the use of richness or diversity indices has two kinds of drawback. Their numerical values are effective in comparing and ranking different habitats within a given study area, but they hardly provide information about the changes of the processes (e.g. in impact assessment of planning scenarios). In other words, they provide little help in assessing the consequences on biodiversity of land-use changes (due to a plan development). Moreover, in some case these indicators may provide controversial results. For example, in the case of a landscape fragmentation, the diversity at community level may remain the same and even increase, if followed by exotic species invasion. The diversity indices might state an “improved” conditions, although the community is compromised with the loss of species unable to survive in isolated and smaller habitat or unable to compete with invasive species (Noss 1990).

Several indicators used in evaluating the biodiversity of an area, such as habitat size, mean nearest-neighbour distance, mean shape index, habitat diversity, terrain complexity (e.g. Lee and Thompson 2005; Margules and Usher 1981; Papadimitriou 2009; Roy and Tomar 2000; Smith and Theberge 1986) raise similar problems: unless meaningful thresholds are defined it is difficult to evaluate disruption in ecological processes. The thresholds allowing the assigning to indices' values an ecological meaning are still debated or not defined. Moreover, these thresholds are dependent on spatial scale of application and on size of study area; thus, even if defined these can be hardly generalized.

This causes the risks that biodiversity is considered by decision makers as a "nebulous concept" and unclear reference for resource management issues. The proliferation of indices and several interpretations can turn biodiversity into a "non-concept" (Hulbert, 1971, in Noss 1990), especially if these indices are used in misleading way (Corry and Nassauer 2005; Failing and Gregory 2003; Li and Wu 2004).

Another difficulty in the use of species richness (or diversity) within plan or project assessment is due to the requirement of species distribution data. The collection of data for calculating diversity indices is laborious in the case of large areas, while their validity has been criticised (e.g. by Alatalo, 1981). In the attempt to solve this criticism, occupation by rare species (for definition, see Rabinowitz, 1981; Rabinowitz *et al.,* 1986; Fiedler & Ahouse, 1992; Gaston, 1994) is generally accepted as indicating that a habitat has a high biological value. However, usually the species data are sampled and gathered for ecology research purposes. Therefore, the species data are available at spatial scales and resolution (e.g. 10 x 10 km grid) not comparable with those on which the plans and projects operate, unless developing specific data sampling campaign.

However, not all levels (and scales) of biodiversity organization are directly affected by the development of a plan or a project. Thus, environmental assessments may efficiently focus on those, among the biodiversity components and functions, which emerge at spatial and temporal range comparable to scales of the spatial planning.

The fauna species are examples of biodiversity and commonly used to represent and study it (Duelli and Obrist 2003); in this case they are named biodiversity surrogates. The surrogates are seen "as intuitive estimation of biodiversity based on theories, models and concepts" (Duelli 1997).

In particular, the "meso-fauna" is the group of small size animal, ranging from amphibians and small birds to mammals (except the carnivorous species), that is more sensitive to land-use changes at local scale. Their populations are dependent on landscape ecological functions, as habitat and dispersal, detectable by maps at scale 1:10.000. Their habitat requirements and home range are comparable with the sizes of areas eventually affected by a local plan (e.g. municipality level), ranging from some hectares to hundreds of hectare. A landscape ecological-based approach to planning may focus effectively on their habitats and functional relationships, for which data is frequently available (e.g. land use/land cover maps) (Fernandes 2000). Henceforth, the proposed methodology focuses on these surrogates of biodiversity.

2.2.2. Habitat loss

The term "habitat" is often used loosely as equivalent to "native vegetation" or other land cover type (e.g. in EUNIS standard). Its precise meaning should be (after Hall and al. 1997) "the resources and conditions present in an area that produce occupancy for a particular species or species assemblage". Thus, since habitat is a species-specific entity, the habitat loss is also species-specific entity. The decreasing availability of resources for the species, the abatement or disappearance of ecological functioning sustaining the life cycle of individuals can cause habitat loss, besides the urbanization of a natural area.

Hence, the amount of a particular land cover type will rarely reflect the amount of suitable habitat for a given species. Habitat and land cover type are not synonymous, as emphasized by aquatic taxa such as amphibians for which the nature of currents and flow patterns together with the attributes of riparian and upland vegetation are important (Gentile and De Bernardi 2004). Therefore, the clearing of native vegetation may be not necessarily a synonymous of habitat loss. Certain species may adapt to the clearing areas. Conversely, an expansion of native vegetation may not be automatically a habitat enlargement. As example, the expansion of forest in Alpine region over declining pastures, due to abandonment of agro-pastoral activities, is threatening plant species diversity and negatively affecting the species of open habitats (Laiolo et al. 2004). In effect, some species are strongly associated with modified landscapes characterized by a historical human use (Chemini and Rizolli 2003). These populations may disappear in such places because of agricultural intensification (Benton et al. 2003; Schmitz et al. 2007) or grazing abandonment (Diemer et al. 2001; Schmitz et al. 2003).

Concluding, an urbanized area should not be considered "non-habitat" for species can survive in the modified landscape. Conversely, the urbanization is not the only way to lose habitats. These can be lost simply changing the resource availability (habitat functioning) and access (habitat connectivity) for certain species. The distinction between habitat loss (by species perspective) and loss of native vegetation cover (by human perspective) is important dealing with ecological consequences of plans and projects.

2.2.3. Habitat fragmentation

Habitat fragmentation is usually defined as a landscape-scale process involving both habitat loss and the breaking apart of habitat (Fahrig 2003). The spatial pattern of fragmentation sets in train a series of negative ecological effects, particularly those that impede fluxes of

organisms, materials (sediment, nutrients, pollen, seeds) and energy, which are essential to ecosystem dynamics and integrity (Lundberg and Moberg 2003).
The study of habitat fragmentation has been contributing to the practice of landscape architecture and planning since two last decades (Collinge 1996). But often 'habitat fragmentation' is used so broadly that it has become vague and ambiguous, thereby limiting its practical value for conservation managers (Lindenmayer and Fischer 2007).
According to Fahrig (2003) the habitat fragmentation implies the following effects on habitat pattern: reduction in habitat amount, increase in number of habitat patches, decrease in sizes of habitat patches, increase in isolation of patches.

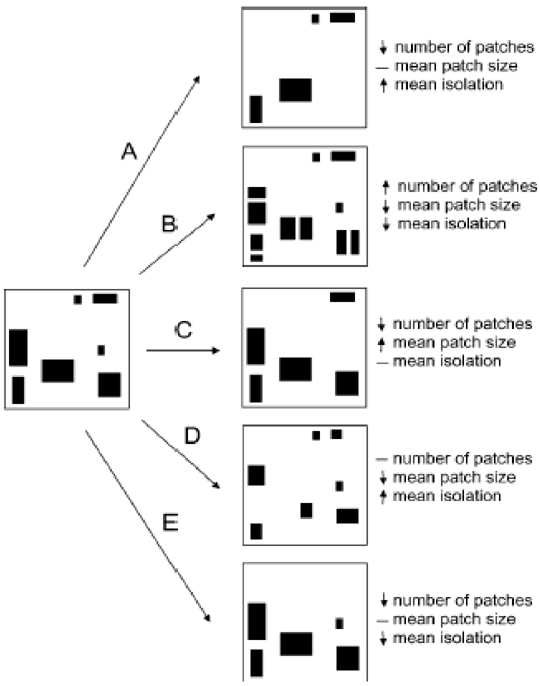


Fig.2.2 Expected effects resulting on landscape pattern in some cases of habitat fragmentation (Fahrig 2003).

Some expected effects of habitat fragmentation on landscape pattern are illustrated in Fig.2.2 by number of patches, mean patch size and mean patch isolation (nearest neighbour distance). Arrows indicate the direction of variables changing. These four effects form the basis for the most frequently used quantitative measures of habitat fragmentation. However, fragmentation measures vary widely; some include only one effect (e.g., reduced habitat amount or reduced patch sizes), whereas others include two or three effects but not all four.
Six steps of landscape fragmentation can be distinguished according to geometric characteristics (Fig, 7) as phases in the change of landscapes (Jaeger 2000b). According to the particular step, different quantitative measures are appropriate to describe the changes of landscape pattern and to relate them to ecological functions (Jaeger 2000b).

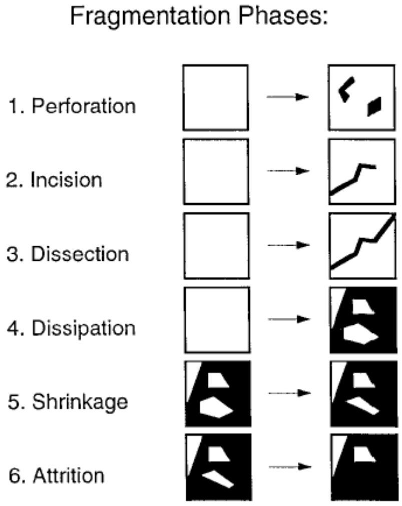


Fig. 2.3 Phases of the fragmentation process (Jaeger 2000b).

The effects of fragmentation on biodiversity can be observed as changes in: abundance/density, richness/diversity, presence/absence, fitness, genetic variability, species interaction, extinction turnover, individual habitat use, movement/dispersal and population growth (Fahrig 2003). Anyhow, results of empirical studies of habitat fragmentation are often difficult to interpret because (a) many researchers measure fragmentation at different spatial scale (e.g. patch scale, or landscape scale), (b) most researchers measure fragmentation in ways that do not distinguish between habitat loss and habitat fragmentation per se (Fahrig 2003).

2.2.4. Connectivity

As fragmentation, the term ‘connectivity’ has become rather diffuse but also controversial. According to Taylor (Taylor et al. 1993) landscape connectivity is ‘the degree to which the landscape facilitates or impedes movement among resource patches’. Similarly, With (1997) defined landscape as connectivity “the functional relationship among habitat patches, owing to the spatial contagion of habitat and the movement responses of organisms to landscape structure”.

According to Lundberg and Moberg (2003) the connectivity is a broader concept. The organisms, that actively move between habitats and ecosystems are important providers of essential ecological functions (e.g. pollination, seed dispersal, translocation of nutrients) (Mills et al. 1993). By connecting areas to one another these organisms, also called “mobile links”, contribute to ecosystem resilience allowing regeneration and recolonization. Mobile links support even the ecosystem capacity to supply ecosystem services (Lundberg and Moberg 2003). In detail, three functions can be recognized (Fig. 2.4): mobile links can support actual ecological processes ("processes linkers"), or drive organic materials ("resource linkers") and genetic information ("genetic linkers") e.g. exchanging seeds and individuals themselves (Lundberg and Moberg 2003). The rate, timing, duration, frequency and spatial extent of a mobile link function could be all affected by habitat fragmentation, leading to profound changes in local ecosystems (Post et al. 1998).

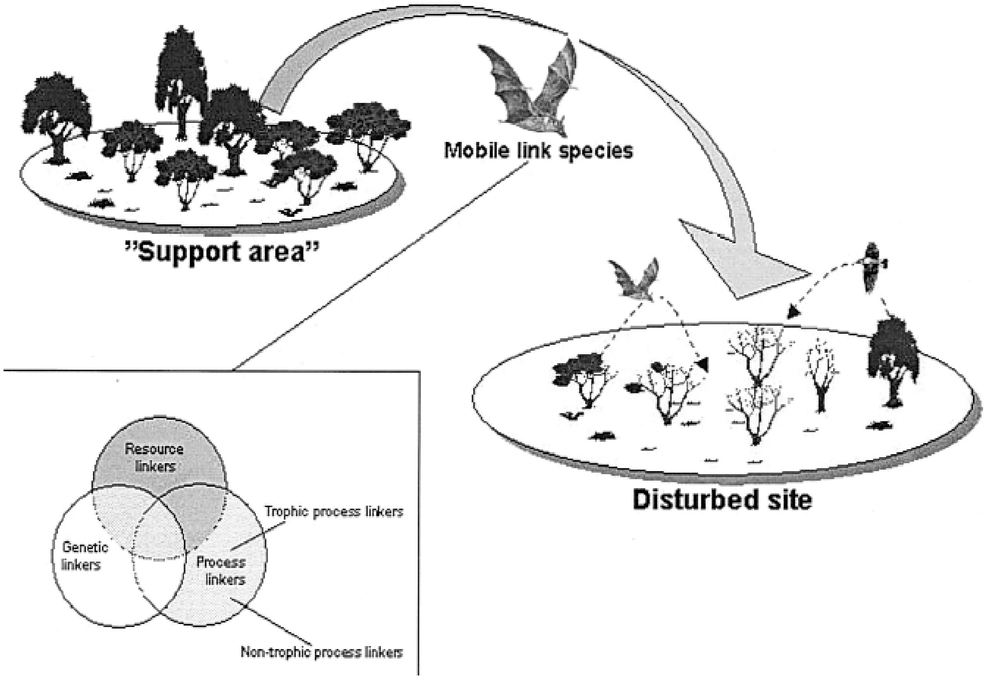


Fig. 2.4 Connectivity as ecological process, supporting ecosystem services, provided by "mobile links" (Lundberg and Moberg 2003).

Connectivity is a primary process influencing ecosystem function and the distribution, abundance and persistence of all biota (Lindenmayer et al. 2007). Moreover, landscape connectivity will play an increasingly important role in the persistence of many plant and animal populations in the face of global climate change and resultant shifts and restructuring of species distributions (e.g. Pitelka et al. 1997, Warren et al. 2001).

In literature, connectivity is appraised in two different manner: as "structural" characteristic or as "functional" (Tischendorf and Fahrig 2000b). Structural connectivity is equated with habitat contiguity and measured by analyzing landscape structure, independent of any attributes of the organism(s) of interest (e.g. Collinge 1996). The functional concept of connectivity explicitly considers the behavioural responses of an organism to the various landscape elements (patches and boundaries).

This distinction between structural and functional connectivity is not a trivial one. The structural connectivity does not provide automatically the information about functional connectivity. Hence, for example, a corridor, i.e. a landscape feature that provides a structural connectivity, does not support a functional connectivity when not used by target species. Functional connectivity, on the other hand, increases when some change in the landscape structure (including but not limited to changes in structural connectivity) increases the degree of movement or flow of organisms through the landscape.

The most used measures of connectivity focus on structural perspective, mainly concerning on how patch area and inter-patch distances affect movement. Measures of structural connectivity ignore variability in the behaviour of the organism(s) in response to the landscape structure and ignore broader-scale influences of landscape structure on finer-scale movement decisions (Tischendorf and Fahrig 2000a).

Structural connectivity is easier to assess than functional connectivity, since it can be easily computed using landscape analysis tools commonly supported by GIS software. Anyhow, according to Tischendorf and Fahrig (2000a) "using structural connectivity in place of landscape connectivity can (and does) lead to inappropriate land-management strategies and obfuscates what might be key problems in managing a given landscape".

Assessing habitat (as well as landscape) connectivity requires a species-centred approach (Hansen & Urban 1992), i.e. the functional perspective. It requires information on species' movement responses to landscape structure, movement rates through different landscape elements, dispersal range, mortality during dispersal and boundary interactions. A given landscape could be perceived simultaneously as connected and disconnected by two species that differ in dispersal characteristics. For example, a road with diurnal vehicle traffic may break apart a habitat for a Ediblefrog, which is unable to pass over it. Conversely, the same road may be negligible barrier for a badger, which preferably moves during night and is able to go easily across a secondary road. Furthermore, the perception of landscape connectivity can change for the same species, depending on its life phases. The nuthatch (*Sitta europaea*) furnishes an example: only the juveniles move across different landscapes for more than 15 km, the adult birds dispersal distances range from about 1 km in continuous forest to around 3 km in highly fragmented landscapes (van Langevelde 2000b). Thus, the same landscape may appear fragmented or not for nuthatches at different ages.

Concluding, landscape connectivity cannot be captured simply by an index of landscape pattern, but should be organism-centred, i.e. based on the organisms' perception of and interaction with, the structure and heterogeneity of the landscape (Taylor et al. 1993). Specifying the focus of analyses, among structural and functional connectivity, is important. Ignoring this difference may hinder a right assessment of the ecological consequences of projects or plans on connectivity.

2.3. Use of key ecological concepts - Review of studies (1997-2007)

Habitat loss, fragmentation and the related issues are main topics by landscape ecology and conservation biology literature, with increasing research efforts (Lindenmayer and Fischer 2006). Conversely, current natural resource management, and generally the spatial/landscape planning, seldom takes into consideration the landscape ecological functions, as habitat functioning, connectivity, and other performed by organisms that move between systems (Lundberg and Moberg 2003). Many studies do not clearly state whether structural or functional connectivity is focused, others confuses patch isolation with connectivity (Tischendorf and Fahrig 2000b) providing in some cases misleading or ambiguous conclusions. As example, Lindenmayer and Fischer (2007) reported two studies, in the same geographical area and conducted simultaneously, achieving opposite results because one focused on patches of remnant vegetation (structural connectivity) but ignored their vegetation structure (providing habitat function and functional connectivity).

Only distinguishing the different processes is possible to identify the underlying mechanisms which threaten species and ecosystems (Fahrig 2003). This will allow quantifying the impacts of landscape change on biodiversity and even developing the effective strategies to counter these impacts (Lindenmayer and Fischer 2007). For example, if habitat loss is the main threat, then increasing size of individual patches of remaining habitat might be the most effective compensatory strategy. Conversely, where habitat subdivision and the resulting habitat isolation are the key problems for a species, then linking habitat patches, i.e. "de-fragmentation" action, might be an adequate strategy.

Through a specific literature review, I aimed to answer three questions: is there the same increasing attention to the fragmentation issues within the field of planning and assessment? Are the above outlined ecological concepts correctly used and distinguished? How these processes are measured? The answers and outcomes of these questions based the theoretical foundation of the present research.

For reviewing the use of mentioned topics, I used the conceptual framework proposed by Lindenmayer and Fischer (2007). To improve the clarity in using the mentioned ecological concepts, they proposed to distinguish within the domain of habitat fragmentation three broad themes or axes of work. Those three axes are: (1) *biological organization and perspective*; (2) *land cover*; and (3) *connectivity*. Their assumption is that "the clear specification of where the focus of a particular study or mitigation strategy lies along the continuum encompassed by these themes will help a precise and consistent use of terms and the effectiveness of environmental assessments".

In detail, *Biological organization and perspective* indicates whether the focus is on a single species or an aggregate measure for multiple taxa (e.g. species richness or assemblage composition) or a human perspective of a landscape. The theme of *land cover*, closely related to the previous theme, requires to specify whether the focus is on either land-cover patterns in a landscape (e.g. as amount and configuration of native vegetation) or on patterns of habitat suitable for a particular species (e.g. particular trees for a hollow-dependent animal species in González-Varo et al. 2008). Within the *connectivity* theme, a distinction is given between connectivity of habitat for certain species, connectivity of human-defined patterns of land cover. The outlined approach is summarized in Tab. 2.1.

Theme and term	Definition
Biological organization and perspective	
Species perspective of a modified landscape	Perception of a landscape by a given (non-human) species; important features include sources of food and shelter, and appropriate climatic conditions[a]
Human perspective of a modified landscape	Perception of a landscape by humans; features include patches of different types of land cover and their spatial arrangement (including native vegetation)[b]
Land cover and habitat	
Species perspective	
Habitat	The resources and conditions present in an area that produce occupancy for a particular species[c]
Habitat loss	Loss of habitat for a given species from an area, precluding that taxon from persisting there; *viz* the area becomes nonhabitat for that species
Habitat degradation	The reduction in quality or condition of an area of habitat for a given species, thereby impairing the demographics of individuals or populations of that species[c]
Habitat sub-division	Breaking apart of a large area of habitat into several smaller areas
Human perspective	
Native vegetation	The cover of vegetation occurring in an area prior to human landscape modification
Native vegetation loss	Removal of native vegetation (e.g. through land clearing)
Native vegetation deterioration	Reduction in the condition of native vegetation (e.g. relative to a specified benchmark for particular structural features)
Vegetation sub-division	Breaking apart of a single large area of vegetation into several smaller areas
Connectivity	
Species perspective	
Habitat connectivity	Functional linkages between habitat patches for a given species: a species-specific entity
Habitat isolation	Functional separation of habitat patches for a given species: a species-specific entity and the opposite of habitat connectivity
Human perspective	
Landscape connectivity	Physical linkage of areas of native vegetation cover within a landscape
Vegetation isolation	Physical separation of patches of vegetation: the opposite of landscape connectivity
Ecological connectivity	Functional linkages of ecological processes at multiple spatial scales (e.g. trophic relationships, disturbance processes and hydroecological flows)[d]

Tab. 2.1 Key themes and associated terms in connectivity/fragmentation issues (Lindenmayer and Fischer 2007).

I used these key themes in reviewing and classifying recent studies published by two groups of journal, reported in Tab. 2.2. The journals were selected by their relevance to landscape ecology and conservation biology studies and to environmental assessment and planning. This distinction aimed to observe the different attention paid to habitat fragmentation/connectivity issues, within different disciplines, in terms of number of papers dedicated to the mentioned issues.

In detail, I searched for papers published in the last 10 years (1997-2007), containing the topics: *habitat networks*, *habitat fragmentation*, *habitat connectivity* or *habitat loss* within abstracts and key words. Then, I classified each paper published by the second group of journals, through the categories of Tab. 2.1, distinguishing human perspective and species perspective, and noting how topics were used, by which approaches and for what purposes.

Tab. 2.2 The two groups of journals reviewed.

1st Journals group Landscape Ecology/Conserv. Biology	2nd Journals group Environment-Landscape Assessment/Management/Planning
Landscape ecology *Conservation Biology* *Biological Conservation*	*Environmental Impact Assessment Review* *Environmental Management* *Environmental Modelling & Assessment* *Environmental Monitoring and Assessment* *Impact Assessment and Project Appraisal* *Landscape and Urban Planning* *Journal of Environmental Management* *Landscape Journal* *Landscape Research* *Journal of Environmental Planning and Management* *Journal o f Environmental Policy and Planning* *Town And Country Planning* *Transportation Planning And Technology*

Obviously, the two journal groups showed a meaningful difference, being differently dedicated to the ecological themes. *Landscape ecology*, for example, published alone more papers than the 13 journals of the second group.

The trend of attention, in terms of number of papers per year, on fragmentation was also different. The trend for the first group of journal was likely exponentially, the trend for second group was increasing too, but slower and steadily (Fig. 2.5).

Many papers of the second group cited simply “fragmentation” or “connectivity” but they did not deal with these issues. Some papers simply discussed theoretically conservation planning strategies involving connectivity or fragmentation analyses.

In detail, 691 papers were published by the first group of journals, precisely: 345 in *Biological Conservation*, 216 in *Conservation Biology* and 130 in *Landscape ecology*. The second group of journals published 82 papers concerning the same topics, with an increasing publication on the fragmentation issue, from 3 (1) papers in 1997 (1998) to 11 in 2006 and 2007. Four journals of thirteen of the second group, related to planning and landscape: *Landscape Journal*, *Town and Country Planning, Transportation Planning and Technology* and the *Journal of Environmental Policy and Planning* seem not have published any paper concerning the fragmentation and habitat loss issues.

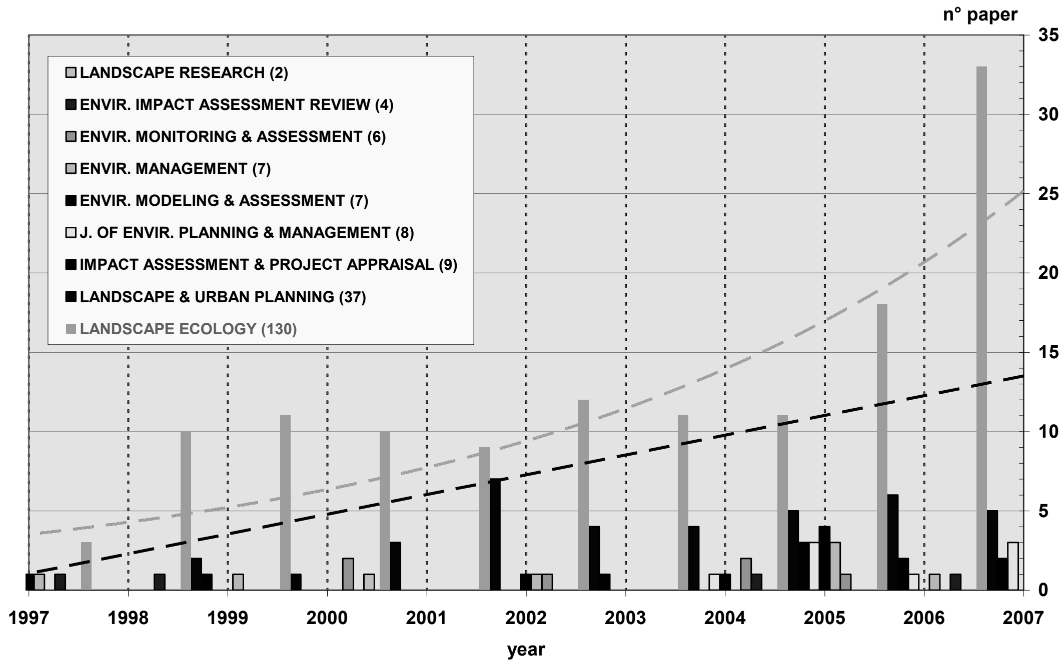


Fig. 2.5 Trend of the use of cited topics in journals reviewed (the green line is a exponential function related only to the *Landscape Ecology* journal, the red one is a linear function fitted to for all journals of the second group).

Among these 82 papers, only 18 explicitly referred to habitats by species perspective (or other taxa). Other 11 papers cited “species” but without stating a defined species (or group) or without effectively using the concept for the analyses of habitat loss or fragmentation. Many papers (62) concerned habitat by the human perspective (see Tab. 2.1). Some papers dealt with *landscape connectivity* as native vegetation contiguity (35 cases), other papers concerned habitat loss as native vegetation cover (25 cases), in some cases both. Besides, 7 papers cited the ecological connectivity theme, but only 2 actually referred to it for assessments or analyses.

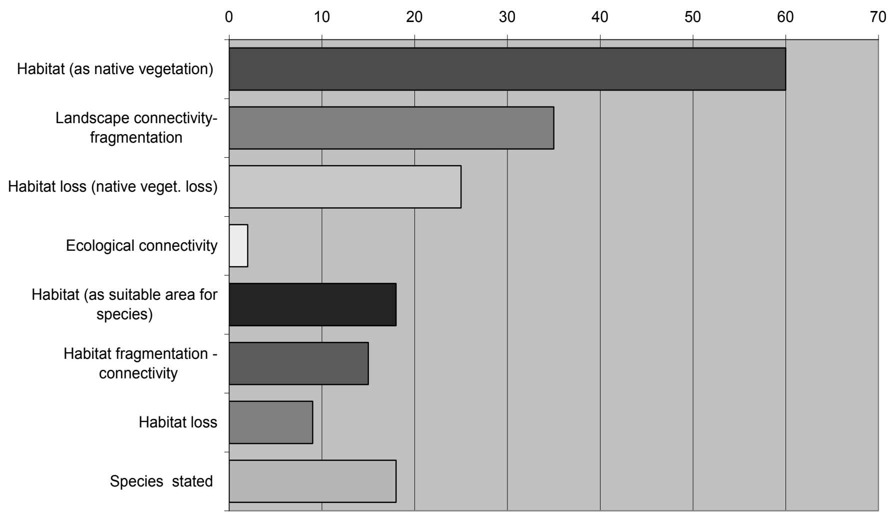


Fig. 2.6 Use of cited terms, by human perspective (the first group), by species perspective (the last four).

The quoted 82 papers used and cited the topics for several objectives and by different approaches. About half of these studies focused on the strategies and approaches to site selection to develop nature reserves or ecological networks. The site selection approaches were based on metapopulation models (e.g. Groeneveld et al. 2005; van Langevelde et al. 2002), or on optimization algorithm to pursue different goals at the same time (e.g. Marshall and Homans 2004; Williams and Snyder 2005). In other case, the main objective was to propose methods and tools for compensatory restoration (e.g. Bruggeman et al. 2005; Strange et al. 2002).

Some studies (17), differently, are focused on the species richness response to environmental (landscape) variables, as a pattern of disturbances and/or pattern of habitat in terms of native vegetation, measured by different landscape metrics (e.g. Lorenzetti and Battisti 2007; Olff and Ritchie 2002; Wickham et al. 1997). Thus, these studies provided some understanding of how fragmentation of native vegetation areas may affect the number of the species. But this understanding hardly provides sound and general reference for assessment of the habitat fragmentation effects (e.g. due to a project construction) on local biodiversity.

Only few papers (12) actually focus on the effects of habitat fragmentation or habitat loss and even fewer used a species perspective. All these papers constitute the base of the following chapters concerning the methods and tools used for the ecological impact assessment of habitat loss and habitat fragmentation (e.g. Gontier et al. 2006; Gulinck and Wagendorp 2002; Mörtberg et al. 2007; Opdam et al. 2006; Opdam and van den Brink 2007).

Concluding, Fahrig (2003) highlighted that in scientific literature there is an undue simplification about habitat fragmentation and loss: neither causes and effects, nor the underlying ecological processes are well distinguished. As verified by literature review, the studies dedicated to environmental assessment and management show the same shortcomings. Even though the habitat fragmentation and loss are processes of increasing concern among ecologists, little attention is dedicated to these themes by the fields of environmental management and spatial planning. In these fields, human perspective dominates habitat analyses and species are seldom considered as a reference, even in assessing the ecological impacts.

2.4. Land-use change consequences within EIA applications

The EIA procedure arranges the analyses of the environmental consequences of single projects, carrying out a project-level approach, in order to get the approval. The aim of EIA is to identify, quantify and to assess the potential impacts of individual projects (such as road, rail, industrial and residential construction or extraction projects) in order to avoid and mitigate the negative effects on the environment. The SEA is a “systematic and comprehensive process of evaluating the environmental effects of a policy, plan or programme and its alternatives, including the preparation of a written report on the findings of that evaluation and using the findings in publicly accountable decision making” (Therivel et al. 1992). Then, SEA is a proactive approach to integrate environmental concerns into policy and plan-making (Stoeglehner and Wegerer 2006).

Both EIA and SEA have similar procedures, even though they encompass a family of tools and instruments with different names, forms and areas of application. The application stages have also analogous objectives, mainly changing the level of planning process in which these procedures are applied: project-level rather than policy or plan-level.

Together these procedures should ensure the environmental aspects to be fully addressed at the earliest stage of general policy level to the single project level. This purpose could be effectively achieved only if EIA and SEA were coordinated with each other. Practically, the two procedures are usually separated. SEA is not required considering details of project-level analyses. On the other hand, EIA is not required discussing strategic decision, handled by SEA studies.

The application of EIA based on project-by-project perspective usually restricts the window of analyses, and it makes difficult to consider impacts to the ecosystems. As a consequence, it is difficult to assess cumulative and widespread impacts at the ecosystem level. On the other hand, SEA procedures applied on regional (or upper level) basis, diminishing the detailing of the assessments, makes difficult to consider effectively the impacts on the habitats or small ecosystems. The EIA/SEA coordination would be essential to assess exactly impacts on biodiversity.

Again, the effectiveness of both assessments is limited especially concerning the impacts on biodiversity or related ecological processes. Even though some improvements can be noticed (Geneletti 2002), generally the quality of ecological assessment in EIA applications remains disputable. In spite of the “criticisms of the ecological content of EIAs has been voiced so often that reinforce it further may seem superfluous” (Treweek 1996), the shortcomings identified along the last decade appears to remain almost the same. Three different syntheses (Tab. 2.3, Tab. 2.4, Tab. 2.5) stress different aspects but they seem to report similar issues.

According to Mandelik et al. (2005), through quality reviews in the United Kingdom (Byron et al., 2000, Gray and Edwards-Jones, 1999, Thompson et al., 1997 and Treweek et al., 1993, in Mandelik et al. 2005) in the United States (Atkinson et al., 2000, ibidem), in Australia (Warken and Buckley 1998, ibidem), in Israel (Mandelik et al., 2002, Mandelik et al., 2005b), in Japan (Tanaka 2001, ibidem), in Sweden (Jong de et al. 2004, ibidem), in Finland (Soderman 2005), in Italy (Geneletti 2002), the biodiversity treatment within EIA applications still reveals serious shortcomings, such as cited in tables below. Their causes are different, and some of these are not easily solvable.

Tab. 2.3 Common criticisms of the ecological content of Environmental Statements (Treweek 1996).

Neglect of key issues
Failure to mention presence of designated areas and/or protected species
Failure to consider other important nature conservation resources which are not designed, or which lie out of the actual site of a proposed development
Failure to characterize baseline conditions or identify nature conservation constraints
Failure to provide the data needed to identify or predict ecological impacts
Failure to measure explanatory variables
Failure to quantify ecological impacts or measure magnitude (even simple, direct impacts like habitat-loss)
Weak prediction
Over-reliance on descriptive and subjective methods
Failure to undertake field surveys
Bias towards easily surveyed and charismatic taxonomic groups
Over-reliance on superficial "walk-over" surveys
Inadequate replication
Failure to estimate ecological significance
Failure to describe limitations or constraints on survey methodology
Recommendations for mitigation measures which do not match impacts
Recommendations for mitigation measures which are untested and unreliable
Failure to name author/consultant or reference sources of data

Tab. 2.4 Overview of the shortcomings in assessment of impacts due to linear infrastructures (Geneletti 2002)

Baseline study	Study area delimited a priori Emphasis on designed sites Incomplete treatment of biodiversity levels
Impact prediction	Lack of quantitative prediction of habitat loss Land-take of project is not justified Lack of use specific indicators for habitat fragmentation
Impact assessment	Vague and mixed-up with impact prediction Assessments are poorly structured and transparent Fragmentation assessed only in descriptive
General remark	Lack of consideration of uncertainty factors

Tab. 2.5 Summary of shortcomings identified in ecological impact assessment (Mandelik et al. 2005)

Baseline description	Failure to address appropriate spatial scale Failure to address all components of biodiversity Lack of quantitative data Low standards of field surveys (reluctance to address spatial and temporal variation)
Impact prediction	Omitting key impact Reluctance to quantify impacts Reluctance to evaluate the significance of impacts Failure to address cumulative, indirect and complex effects
Mitigation and monitoring	Severe impact left-unmitigated Recommendation of un-testable measures Reluctance to evaluate the efficacy of proposed measures Reluctance to mention the need for or propose adequate monitoring program

It is possible distinguishing three general sources of shortcomings. The first is associated to lacking data, lacking of resources for field surveys, difficulties of measurements of ecological processes and biodiversity components. This is often due to the constraints proper of organizational contexts of EIA applications, i.e. limited human resources, time and funds are common problems within environmental assessments and decisions (Cortés et al. 2000).
The second limitation concerns the understanding of ecological dynamics. Many of the scientific and technical problems associated with environmental impact assessment can ultimately be traced back to the natural variability inherent in ecological processes. Ecology itself is a "science weakly predictive" (Treweek et al. 2006).
The third source of shortcomings is related to ambiguous interpretations (and measurements) of ecological terms, like as "biodiversity" (see § 2.1), and to the definition of the values (as "nature value" or "ecological significance"). Assessing an "ecological impact" involves the definition of conservation value for affected environment. Different motivations for assessing aspects of biodiversity lead to different value systems (Duelli and Obrist 2003). These values are rarely quantified (Geneletti 2002) and their definition may have not clear relations with ecological functioning of the environmental component of concern, or with its providing ecosystem services. Besides, the definition of conservation priority between, for example, a small pond with threatened amphibian species and a species-rich grassland is a complex task, which may need more than only the ecologists judgement (Curtis 2004).
In spite of all this, the EIA remains a necessary tool of environmental planning and management (Morgan 1998). In many instances it is even the only stage during the planning process in which the ecological consequences of the local development actions are being considered (Mandelik et al. 2005). This situation requires further and urgent improvements of assessment methodologies. These methodologies should focus especially to define the ecological processes more sensitive to land cover changes in a territory, to identify the development actions that affect more these processes and to understand the relations between these processes and actions.

2.5. An expert-based support system for environmental assessment for the same study area

The present research was motivated by the results of a previous project. This project was meant to provide an assessement of biodiversity assets for the Trento Province (northern Italy), implementing it into an environmental decision support system (DSS), the Information System of Ecological Value *(Sistema Informativo della Sensibilità Ambientale*, SISA). In particular, the information system, based on available data sets, aimed to support *screening* stage of EIA.
The *screening* stage involves the selection of projects that should be assessed by EIA procedure, according to the criteria related to the sizes of the project or to the "environmental

sensitivity" of a construction site (EC 2001). The SISA focused properly on "environmental sensitivity", defininig "warning levels" according with ecological relevance of sites, i.e. the sensitivity of areas to the project development. The warning level map identifies where the projects are likely to have significant impacts on the environment.
The project was formerly tailored for the Avisio River Basin, in Trento Province (Geneletti 2008), subsequently it was extended and adjusted to the whole Trento province, (Diamantini et al. 2004; Diamantini et al. 2007; Scolozzi 2007; Scolozzi and Geneletti 2007).
Building the information system entailed spatial and non-spatial multicriteria evaluations based on the expert judgment. The experts' judgments were gathered by interviews, thematic Delphi surveys and interdisciplinary Focus Groups. The project provided to the main user, the Environmental Protection Agency of Trento province (EPA-Trento), an updatable information system and operative tool, now used by EPA-EIA Office. Nevertheless, some shortcomings can be identified; these have suggested the present research.

2.5.1. Development steps of the support system

The thematic map of ecological relevance, for the whole Trento province, is the main output of SISA. This refers to the suitability of a site for sustaining a certain degree of biodiversity. More valuable sites provide the higher "warning levels". The assessment procedure is based on a deductive approach in which the selected experts assess a biodiversity value according to characteristics of the sites. The experts were selected with the aim to include different expert opinions, belonging to both reseaech institutes and public administration technical offices. The expert evaluations were converted in value maps, and then integrated into a geographical information system, taking structure of a DSS.
The assessment framework considers two levels of biodiversity divided in six themes: the species level, considering plant and animal species, the ecosystem level, taking into account freshwater ecosystems, forest ecosystems, agro-ecosystems, Alpine ecosystems. The assessment was carried out through four procedural steps: building of knowledge framework, expert-based evaluation, mapping of the valued criteria and synthesis of the findings into a final thematic map (Fig. 2.7). Each different biodiversity component involved different group of experts and different evaluation approaches, i.e. different methods and criteria, as abstracted in Tab. 2.7.
The baseline data were obtained from government agencies (that routinely acquire them); in some cases data were generated from such data with relatively little efforts. All the themes were constructed at 1:10.000 scale, according to the planning practice at a regional level.

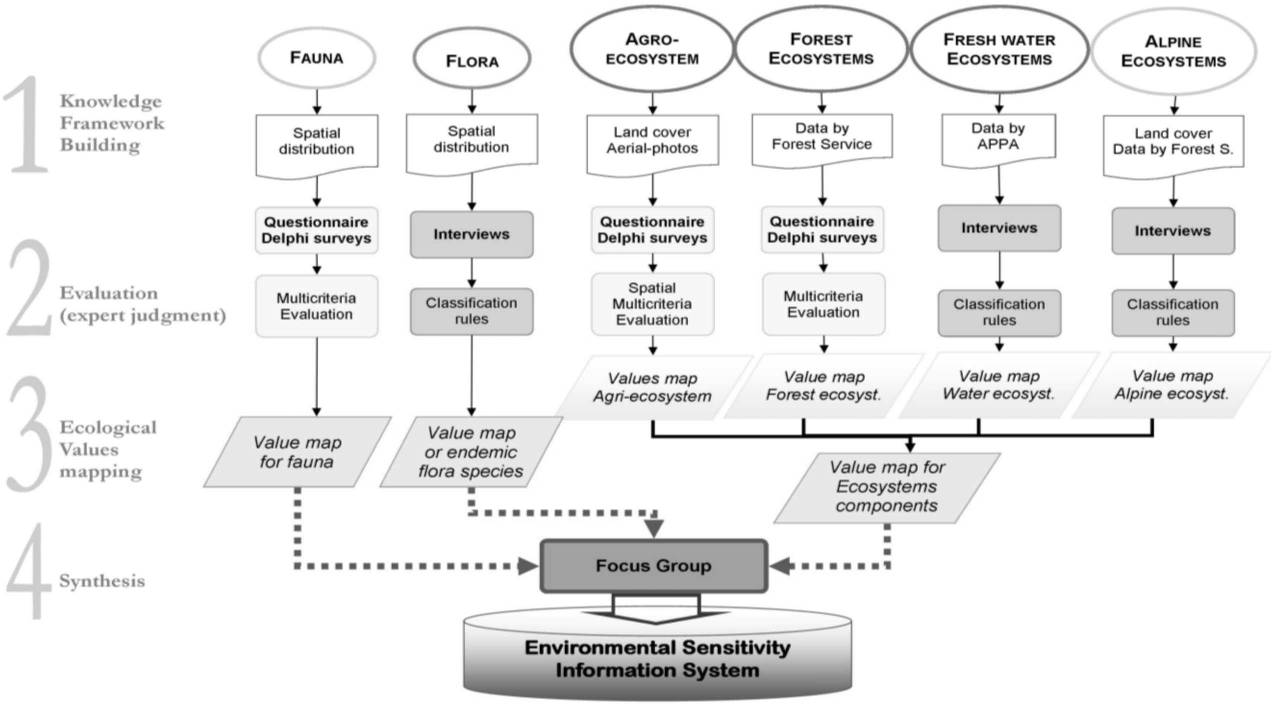


Fig. 2.7 Development steps of SISA.

In detail, the evaluations establishing the Fauna theme considered a set of species distribution maps, provided by the Wildlife Management Plan of Trentino, which is periodically revised and updated. The species set included 16 animal species related to the hunting interest or with threatened population depending on human intervention, namely: Roe Deer (*Capreolus capreolus*), Elk (*Cervus elaphus*), Chamois (*Rupicapra rupicapra*), Mouflon (*Ovis musimon*), Ibex (*Capra ibex*), Capercaille (*Tetrao urogallus*), Eurasian Black Grouse (*Lyrurus tetrix*), Rock Ptarmigan (*Lagopus mutus*), Hazel Grouse (*Tetrastes bonasia*), and Rock Partridge (*Alectoris graeca*), Bear (*Ursus acrtos*), Wild Boar (*Sus scrofa*), Lynx (*Lynx lynx*), Blue Hare (*Lepus timidus*), Alpine Marmot (*Marmota marmota*), Rabbit (*Aryctolagus cuniculus*). Since the distribution maps had a coarse resolution (i.e. species occurrence recorded within a 1 km x 1 km grid), these were improved by selecting only the suitable land covers within occupied cells. In addition, different buffer zones were defined, assuming different species-specific response to different disturbance sources (such as roads, settlements). Thus, the several buffer zones, encompassing urban and other likely disturbing areas, were clipped from each map. Subsequently, an overall value map was generated through summation of the values of the species likely residing at each location.
In the Flora theme occurrence maps of 46 endemic plant species were used. The endemic plant species were used for their intrinsic biodiversity value. Endemic species distribution maps (Prosser 1998), available at a very coarse spatial resolution (5 km x 5 km grid), were improved by a similar approach used for animal species, basing on suitable land covers, slope orientations and altitude belts. An overall value map was generated through summation

of Biodiversity Erosion Risk index (BER)(Fattorini and Giacanelli 2004) assessed for the species likely present at each location.

The Agro-ecosystem theme was based on landscape ecological indicators and on an application of multicriteria analysis (Geneletti 2007). The data used in Forest Ecosystems theme was the Forest inventory based on parcels, carried out by the Forest Department of Trento Province and regularly updated. Data collected from several departments and agencies based the evaluations for the Freshwater Ecosystems theme, which considered separately running and standing water bodies. In effect, different kinds of water bodies are monitored for different purposes by different agencies. Each agency applies different indicators, as Fluvial Functioning Index for rivers (Siligardi et al. 2007), or Ecological Quality of Body Water index for lakes (SECA, according to Italian Act 152/99). Besides, many secondary water bodies are not monitored, thus lacking of data. The Alpine Ecosystem theme was constructed by extracting natural features, occurring above the tree level, from available land cover map.

In the second step, for each sub-theme a set of criteria and an assessment approach was proposed and developed in collaboration with selected experts. At the beginning, to define the sets of criteria and the evaluation scheme exploratory interviews were performed involving experts from the most of provincial services related to environment monitoring or assessment. Then, several groups of experts shared and evaluated the criteria sets (Tab. 2.6). Depending upon the number of experts, Delphi surveys or interviews were used to collect opinions (Tab. 2.6). A Delphi survey consists of an iterative process of individual expert consultation and knowledge accumulation that it is repeated until a certain degree of judgements convergence is attained (MacMillan and Marshall 2006).

As example, for the particular case of Freshwater Ecosystem theme, a multi-method approach was developed with experts' collaboration, considering all the available data and providing a case-based reasoning approach when lacking data (

Fig. 2.8). In detail, a rule-based approach was based on ecological quality indices when available (as FFI), otherwise on multicriteria evaluation morphological fitted (modifying criteria scores and weighs) to experts' evaluations of known cases. The set of criteria relied on variables obtained from DTM, such as average slope, Sthraler fluvial order, and average elevation and on naturalness of river bed (previously monitored by Faunistic Office of Trento Province).

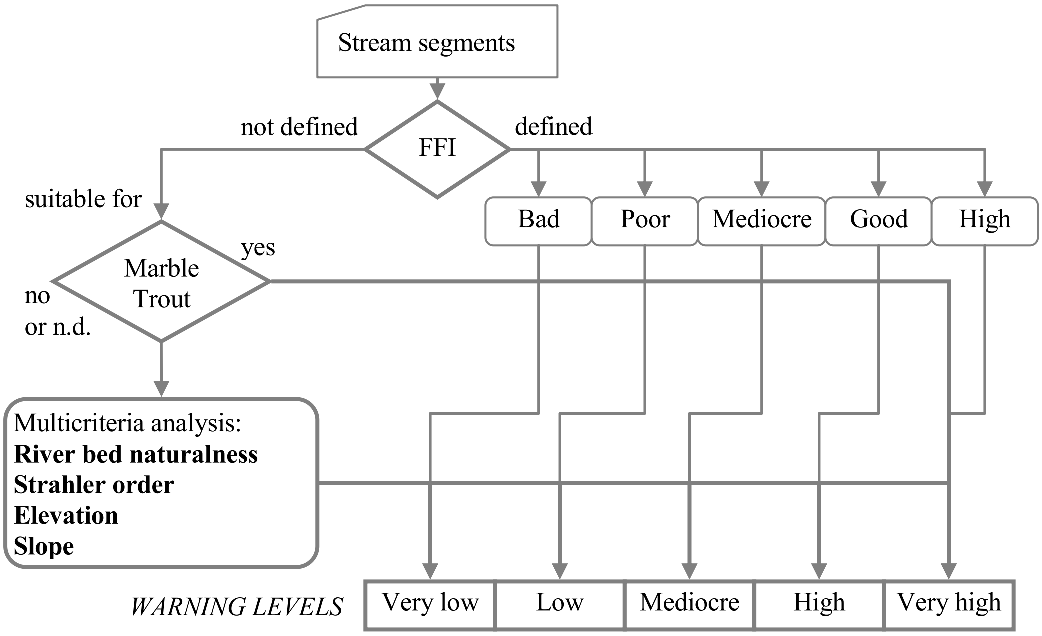


Fig. 2.8 Rule based classification for Freshwater Ecosystems theme (concerning running water bodies).

In the third phase, a value map for each sub-theme was obtained (Fig. 2.7), applying the different evaluation schemes. In the last phase, a smaller group of experts, "multidisciplinary experts", contributed to the three sessions of a Focus Group, in order to define a synthesis from the value maps. In detail, these sessions focused on: a) discussing the previous results and sharing the value scale for each sub-theme, b) discussing and sharing a method by which to aggregate the sub-themes, c) to evaluating the whole process and providing suggestions for further development.

The themes were integrated in a composite map providing a concise representation of biodiversity assets for the whole province of Trento. This map consisted in a mosaic of theme maps concerning the ecosystems, previously reclassified in five classes. The mosaic was meant that the different themes were not overlapping but arranging a complete cover for study region. The reclassification followed the Focus group indications and a specific request of end users about number of five classes, to not hamper the applicability of the results. The reclassification considered separately the themes, each by own evaluation reference, abstaining from compare ecological relevance of different theme features. The themes concerning the species (Flora and Fauna) were integrated on the composite map only as ancillary attributes because the species used, according to experts' opinion, are not representative of the whole province biodiversity, even though they provide useful information.

Tab. 2.6 Different contributions provided by different institution experts.

Knowledge contribution	N° of experts	Institution/organization
Flora (by Interviews)	2	Museo Civico di Rovereto Botanic professional
Alpine ecosystems (by Interviews)	2	ISAFA (Istituto Sperimentale Per L'assestamento Forestale e L'apicoltura) Botanic professional
Fauna (by Delphi survey)	22	Centre for Alpine Ecology (CEA) Natural History Museum of Trento (MTSN) Provincial Forest and Fauna Service Associations/clubs: Ass. Cacciatori Trentini, WWF-Trentino, Italia Nostra, LIPU
Forest Ecosystem s (by Delphi survey)	12	CEA Provincial Forest and Fauna Service
Water Ecosystems (by Focus Group)	8	Provincial Environment Protection Agency Istituto Agrario San Michele all'Adige (IASMA) MTSN
Agro-Ecosystems (by Delphi survey)	4	IASMA Provincial Department of Agriculture and Alimentation
Synthesis Integration phase (by Focus Group)	8	Department of Agriculture and Alimentation Natural Park and Nature Conservation Service APPA, CEA, IASMA, Museo Civico di Rovereto, MTSN,

All information generated during the development stages (Fig. 2.7), i.e. thematic map layers, metadata, attributes and values judgments, was organized in a DSS, composed by a geographical information system with a customised querying interface. The interface, developed using *hotlink* function within ArcView3.2, allows accessing to all information through sequential queries. These queries provide progressively increasing details of spatial and non-spatial information, structured hierarchically. The querying system consists in 4 levels, ranging information from the warning level map for the whole province, to the results of Delphi survey and specific descriptions of assessment approaches.

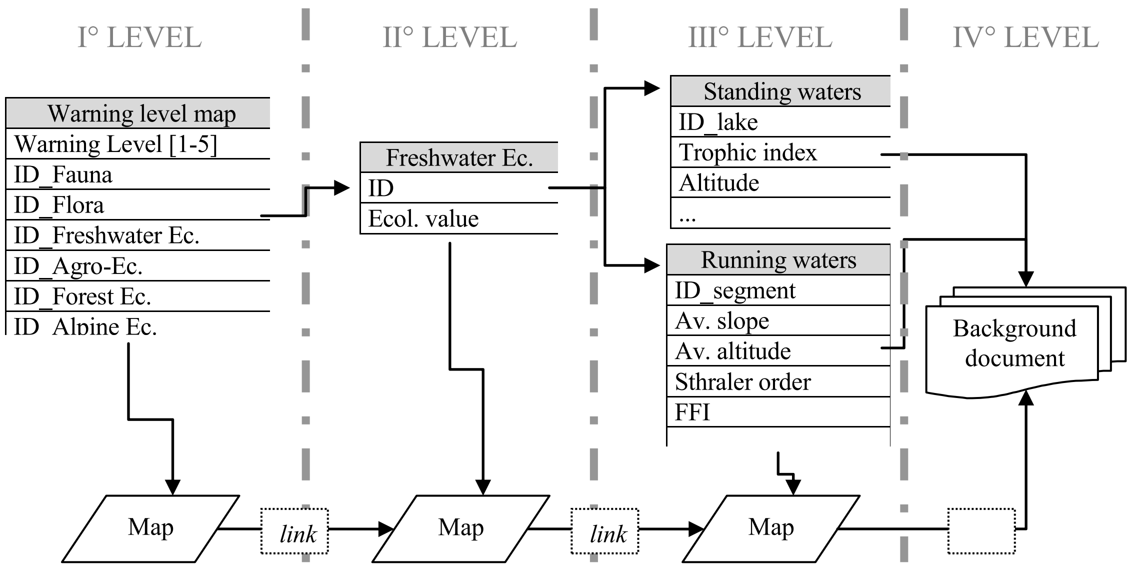


Fig. 2.9 Structure of geodatabase and hierarchical querying system (example of Freshwater ecosystem theme).

2.5.2. Strength points of the SISA

Since the former version of SISA, tailored to Avisio river basin, meetings were held with EPA officers in order to collect feedback, and accordingly revise the method and the tool (Geneletti 2008). EPA officers stressed strengths as transparency, rapidity and consistency of results. In particular, the consistency the use of SISA ensured that all projects submitted to screening were assessed against the same reference framework, i.e. using the same data and the same pre-defined and commonly accepted evaluation scheme. These strengths characterizes also the actual version of SISA.

The expert-based information system seems to be an effective and practical tool supporting the screening phase within EIA procedure. EPA-EIA officers query routinely the SISA, gaining an understanding of the overall consequences of proposed project with respect to the distribution of biodiversity assets and quickly pinpointing the relevant biodiversity issues of concern. The system allows easily obtaining information about environmental values, for any location.

The whole assessment procedure is re-viewable and updatable once new knowledge is available. The updating may involve the modification of variables in evaluation procedure such as criteria or their weights, or the addition of new environmental components e.g. another species distribution.

The system provides to users reliable value information, obtained from descriptive data provided by several province services. The number of institutions and of experts participating to the evaluations, belonging to both research institutes and public administration technical offices, contributed to the reliability of the SISA. The value information provided may support land use decisions over and above environmental impact assessments. Besides, it is contributing to ease the problem of obtainability of environmental evaluations, based on data dispersed among different services and agencies.

The definition of warning levels is particularly important for outside protected areas. The study generated a map representing a gradation of values for the whole province. This may facilitate going beyond the perspective of ecological evaluation strictly focused on nature reserves, still common in planning practice and environmental assessments (e.g. Byron 2000).

Concluding, the development process of SISA provided also a learning experience: during the Focus Groups both participants and facilitator-researchers could learn about other fields and shared new viewpoints. Nevertheless, this application has weak points; some due to difficulties encountered in developing the procedure, some other were inherent to the methodology.

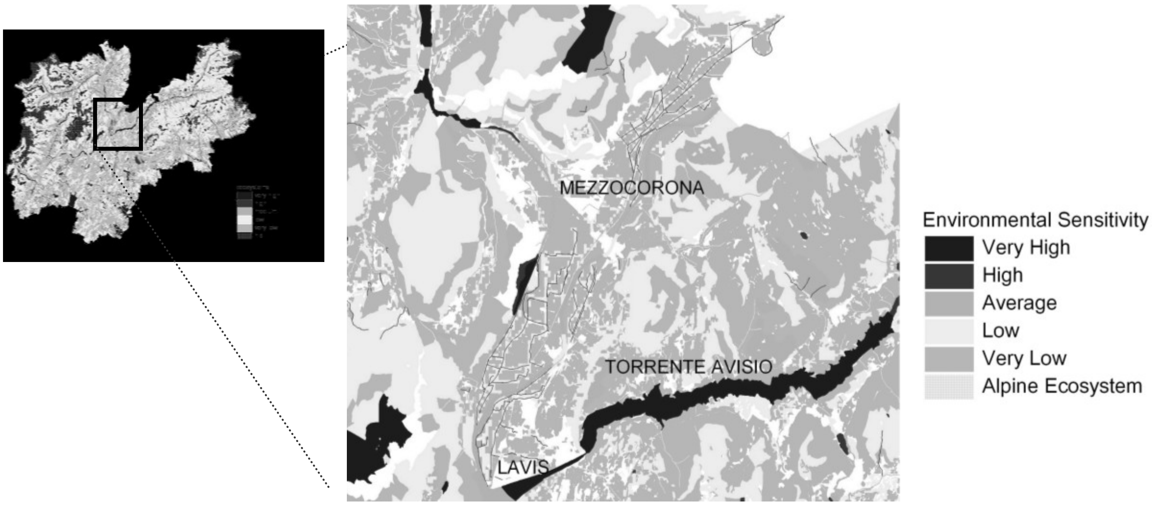


Fig. 2.10: A sample of the SISA thematic map.

2.5.3. Weak points

Main weaknesses of SISA were due to the fact that assessment methodology had to rely only on the available data, routinely acquired by provincial agencies, or that can be generated from such data with relatively little effort. This data have been produced for different goals by different province services, not coordinated in sampling and monitoring the several aspects of biodiversity. Consequently, not all themes were treated with the same level of details. The scarce availability of data affected criteria definition and related evaluations.

The used animal species, in Fauna theme, does not represent the biodiversity of Trento province (at species level), rather game interest (as ungulates or game birds) or flagship species (i.e. charismatic and threatened species as bear or lynx). In particular, these species are related to Alpine and mountain habitats rather than to the different ecosystems of province. These species were used simply because their distribution data are available, without a previous selection based on their ecological role or relevance. As consequences, the resulted fauna value map is biased and unbalanced towards game species habitat: basically woodlands of high altitudes. None of habitats for amphibians or reptiles invertebrates is considered. Hence, all other habitats than mountain or Alpine areas have been poorly valued because lacking the Alpine fauna species, but not for real ecological reasons. Lower belts, valley floors and the related habitats are thoroughly neglected.

Comparable issue concerns the Flora theme. The endemic flora species are result of post-glacial population dynamics and they are distributed in particular areas at high altitudes. Although the endemic species are usually rare and threatened species and often used an effective umbrella for overall species richness of a region (Bonn et al. 2002), they do not guarantee the representation of overall plant species, and also not necessarily indicate the ecological quality of a site. Particularly they are not sufficient to represent overall species diversity in a region where the highest biodiversity resides in lower and more stressed belts (Bonavita et al. 1998; Chemini and Rizolli 2003). Therefore, the valley floor areas and all related habitats remain undervalued, even though they can provide irreplaceable sites for biodiversity conservation.

The Fresh-water ecosystems were assessed combining evaluation methods; this provided unpredictable uncertainty in results. This was due to the fact that different amount of information was available for different water bodies. Lakes and main rivers have been monitored for relatively long period; conversely few data are available for minor streams and ponds. This required mixing different data with different spatial and thematic resolution in a rule-based classification, in order to achieve anyhow some conclusions. As consequence it was not possible estimate the uncertainty or the results' sensitivity to assumptions or environmental variables used.

The number of available and acknowledged experts affected the expert judgement gathering. Not for all sub-themes it was possible to conduct a Delphi survey because of lacking an adequate number of experts. In the evaluations for Flora theme only two botanic experts participated. In the Delphi survey for Agro-ecosystems theme, after having achieved a relatively poor agreement on criteria weighs, it was not possible reiterate the questionnaire round because too few experts answered to the last round.

Experts themselves, during the Focus Groups, suggested some weak points. As the experts pointed out, the species level of biodiversity is the weakest part of the information system. In particular, the information system undervalues the small habitats nearby and among urbanized areas at valley floors. These habitats are important because of location, under increasing pressure, and because they are the remnant natural areas with relatively high biodiversity. Anyhow, remnant vegetation patches, at valley floors, may represent important stepping stones along migratory routes or for seasonal animal moving.

From theoretical perspective, the whole assessment procedure seems to be based on a static concept of ecological communities. There is little consideration of how the ecosystem might evolve in spite of nearby land-use changes. The matrix of surroundings land seems to not having significant effect on the species composition then on the ecological relevance of areas. Dispersal requirements of species, i.e. spatial relationships and ecological linkages between habitats, are not considered.

2.5.4. Further development

The experts themselves, during the Focus Group sessions, suggested some further developments. Essentially two correlated indications can resume possible further developments.

Improve the biodiversity evaluation, taking into account the processes. As starting point, using on a larger number of species, some habitat suitability models (e.g. Boitani et al. 2002) may be easily applied, requiring only available land-use data. This may partially solve the problem of the biased and unbalanced value maps. This allows assessing the areas actually lacking data. In order to evaluate effectively the environmental sensitivity, the processes sustaining the local biodiversity should be also considered (as habitat potentialand functional connectivity), going beyond the number of present species. The simple number of biodiversity entities present cannot describe functionality, persistence, productivity and resilience of a system. In particular, it may be effective considering the landscape ecological functioning, e.g. "ecologically scaled landscape indices" (Vos et al. 2001), based on species indicators. These species should be representative of different habitat types (i.e. wetland, grassland) and of different groups of animals (e.g. birds, reptiles, amphibians, insects, mammals), in order to use their habitat requirements as effective references for a landscape ecological assessment (Mörtberg et al. 2007). This assessment should consider the dispersal requirements of species, i.e. ecological linkages (i.e. spatial relations) between habitats.

Consider a biodiversity "potential value" and broaden the assessment perspective. This means to try answering to the question of how much diversity is enough, with respect of the status quo, the past and trends for a certain location (Main 1999). Identifying the recent shift from a natural condition to the present condition allows depicting possible reverse trends and defining the potential for restoration (Noss 1999). Considering the spatial relations with surrounding land uses and habitats might support the role definition for a defined area in sustaining ecological processes, i.e. its potential for sustaining biodiversity. Considering not only the status quo but also the possible future role, in other words the dynamics of land uses, might support better decision for environmental impact assessment and also for compensation and mitigation measures. This may solve a risk, stressed by an expert involved in the Focus group, of considering the low value (i.e. low warning level) areas simply as "available areas" for construction. Low value areas may have potential of feasible restoration. Developing project on them may prejudice the possibility of restoration in future, also for nearby areas (Bigaran 2006, personal communication).

Another further development may be the integration of the ecosystem services within the DSS. The actual assessment scheme assigned to small streams, headwater streams at valley floor and ditches a low or very low value, in spite of their significant ecosystem services (Maiolini 2006, personal communication). These streams may play important role in maintenance of natural discharge regimes, regulation of sediment export, retention of nutrients, processing of terrestrial organic matter (Winsor and Gene 2005). At landscape scale, high levels of habitat diversity among and within these small streams create niches for diverse organisms, including headwater-specialist species of aquatic invertebrates, amphibians. The ecosystem services provided by headwaters and the species they support are very sensitive to natural and anthropogenic disturbance of surrounding lands (Winsor and Gene 2005). Only considering overall these aspects will be possible to obtain comprehensive evaluation of ecological relevance of sites.

Tab. 2.7 Details of the evaluation phase within SISA developing.

Sub-theme	Indicator/evaluation approach	Evaluation criteria	Spatial/ Non Spatial	Knowledge Elicitation tools	Basic data used
Forest Ecosystems	Multicriteria evaluation of wood classes	▪ Naturalness ▪ Extinction risk ▪ Local habitat heterogeneity	NS NS S	Delphi Survey (wood classes assessment by cited criteria, criteria weighing)	Forest parcels data and map (wood classes)
Agro-ecosystems	Multicriteria evaluation based on criteria maps related to biodiversity potential	▪ Agricultural landscape type ▪ Vegetation remnants ▪ Proximity to nature reserves ▪ Ecotones ▪ Local habitat heterogeneity	NS S S S S	Delphi Survey (criteria weighing)	Land cover Aerial-photos
Fresh-water Ecosystems	Multi-method approach focusing on community richness, ecosystem vulnerability, ecosystem services, naturalness, ecological functioning, ecosystem integrity	▪ Altitude ▪ Slope ▪ Strahler fluvial order ▪ River bed naturalness ▪ Fluvial Functioning Index ▪ ISPI T/R index ▪ ISECI	S S S NS S NS NS	Interviews Focus Group (criteria definition, criteria evaluation and weighing)	DTM Stream network Land cover Water quality monitoring data
Alpine Ecosystem	n.d.	(not defined)	n.d.	Interviews	Land cover
Fauna	Multicriteria evaluation of sites by sum of species potentially present weighed by ecological relevance, defined through the following criteria	▪ Trophic level ▪ Stenoecia ▪ Natural rarity ▪ Sensitivity ▪ Vulnerability	NS NS NS NS NS	Delphi Survey (criteria assessment, criteria weighing)	16 animal species distribution
Flora	Evaluation of sites by sum of endemic species valued according to Biodiversity erosion risk (BER) index	▪ BER index	NS	Interviews (criteria definition)	43 endemic flora species distribution

2.6. Effective steps towards sustainable landscape planning

Human activities affect different components of biodiversity in an area, in terms of composition, structure (organization in time and space) and key processes (ecological functions). In a sustainable landscape, the spatial pattern of ecosystems should allow populations of targeted species (biodiversity surrogates) to survive. Wide literature indicates that the persistence of species populations in a landscape depends in large measure on the area and spatial configuration (connectivity) of good quality habitat (habitat functioning) (e.g. Gentile and De Bernardi 2004; Hanski 1994; Verboom et al. 2001a).

There are plenty of available indices dealing with spatial configuration of landscapes. Often they are used to implicitly infer insights about a landscape "quality". To be useful to the planners and designers they should be both reliable and valid for landscapes at the scale of decision-making. The meaning and interpretation of index values in any given application is not intrinsic to any landscape pattern. Although currently available indices appear to be reliable measures and may usefully document differences in landscape patterns, they are not consistently valid measures of species habitat quality (Opdam et al. 2001).

Besides, since the species have different scale-dependent responses to landscape characteristics, any landscape index that fails to account for this scale-dependent variation has no ecological significance (Vos et al. 2001). These include the neutral measures proposed by, among others, Franklin and Forman (1987), O'Neill et al. (1988), Turner et al. (1996), Ripple et al. (1991), McGarrigal and Marks (1995) and Gustafson (1998) (all cited in Vos et al. 2001). For these reasons, Vos et al. (2001) claimed to develop "ecologically scaled landscape indices" that are indices explicitly referring to ecological processes.

To survive, a species population should hold a minimum number of individuals, which equals a minimum amount of ecosystem area consisting of functioning habitats for the species. Therefore, four main issues may be recognized as needed in spatial planning aiming at sustainable landscape:

- Landscape classification for habitat definition and functioning analyses
- Species definition for biodiversity surrogates-based assessments
- Fragmentation/connectivity analyses
- Assessment of habitat networks functioning

In the following paragraph, approaches and methods supposed to be effective in supporting spatial planning and environmental assessment are presented. They provided the theoretical and operational references for developing the proposed methodology, presented in following chapters.

2.6.1. Landscape classification for habitat assessment

The landscape classification is the most important issues to be considered in developing approaches to sustainable landscape (Lindenmayer et al. 2007). It involves using a conceptual model to characterize a landscape, grouping landscape elements into categories and/or allocating entire landscapes into classes based on the amount and distribution of landscape attributes. Landscapes can be classified using: structural attributes, such as the amount and configuration of vegetation (e.g. Forman 1995); habitat for a particular species (e.g. Fischer et al. 2004) and functional attributes or landscape processes (e.g. Ludwig et al. 1997, in Lindenmayer et al. 2007).

Despite many alternative models, many studies often apply the Forman's (1995) patch-corridor-matrix model to classify landscapes, particularly those concerning landscape subject to human modification, as in most of fragmentation studies (Haila 2002). Such simple models often portray landscapes in a binary form composed of habitat and non-habitat and, therefore, fail to consider many other important aspects of landscapes. The binary habitat definition usually refers to native vegetation cover (e.g. woodlands). Native vegetation cover may be a useful concept on continents such as the South and North America and Australia where it often relates to pre-European vegetation, but it is less relevant from a European perspective because many landscapes and vegetation types have a prolonged history of human modification and management (Lindenmayer et al. 2007).

Habitat models are relevant for addressing issues within environmental assessments at landscape level (Fernandes 2000; Gontier et al. 2006). To classify landscapes by species habitat the Habitat Suitability models are the most diffused. Usually fundamental elements of every habitat suitability model are the environmental variables (independent variables), the resulting habitat suitability values (dependent variables) and the classification function that links the two (Pedrotti and Preatoni, 1995, in Ortigosa et al. 2000). These classification functions commonly scale (both linearly and nonlinearly) each environmental variable between 0 and a maximum value (often 1) and then denote habitat suitability for a species as a function (more or less complicated) of these scaled values. The environmental variables are, for example, meteo-climatic, morphological, trophic, vegetation, anthropic variables (see a short review in Ortigosa et al. 2000).

US Fish and Wildlife Service (1986) developed more than 350 Habitat Suitability models (for more than 350 species). For Italy, an extensive modelling was developed by Boitani et al. (2002), concerning 182 species of Italian vertebrates. Both these groups of models are expert-based. Example of non expert-based habitat-suitability models are the Generalized Linear Model (GLM) and the Ecological Niche Factor Analysis (ENFA) (Hirzel et al. 2001), which use empirical data.

A different approach is provided by Löfvenhaft et al.(2004) that proposed a qualitative classification of habitat functioning. Qualitative classes/categories indicate particular habitat functions provided by landscape elements; thus a land covers are distinguished by providing, for example, breeding sites or feeding resources.

2.6.2. Species indicator selection

The habitat models, in accordance with the mentioned definition of habitat (§ 2.3.2), have to be based on species habitat requirements. The models refer usually to one or few species (species indicator), which are supposed to serve as surrogates for biodiversity as a whole. Species indicator could be defined as a characteristic which, when measured repeatedly, demonstrates ecological trends and a measure of the current state or quality of an area (Ferris & Humphrey, 1999).

Species have been used in ecology and conservation for over a century in a variety of ways. Examples of species indicator use are: as definition reference for "life zones" by Hall and Grinnel (1919); as bio-indicator for verification of compliance of industries to specific anti-pollution laws by Mac Donald and Smart (1993); as ecological indicator to assess habitat quality by e.g. Powell and Powell (1986) or Canterbury et al. (2000) (cited in Carignan and Villard 2002). Recently, the species indicators are used in landscape planning (e.g. Bani et al. 2002; Bianconi et al. 2003; Padoa-Schioppa et al. 2006) and in landscape ecological assessment (e.g. Mörtberg et al. 2007; Vos et al. 2001).

The species indicators are useful and selective if their selection is based on un-biased information on species' responses to habitat loss and alteration (Favreau et al. 2006; Lindenmayer et al. 2002a). A diffused approach to select species to develop landscape indicators is the *focal species* concept (Lambeck 1997): the most area-sensitive, dispersal-limited, resource-limited and ecological process-limited taxa, in a landscape. The idea is that a landscape designed and managed to meet their needs will encompass the needs of all other species. These indicator species "indicate condition or a response to stress that may apply to other species with similar ecological requirements" (Niemi & McDonald 2004 in Bani et al. 2002).

Lambeck (1997) proposed a methodology for selection of the focal species and application in biodiversity conservation planning, involving: 1) the identification of threats and 2) the identification of focal species and 3) description of their critical requirements relative to those threats. To select effective indicator species the selection should also fulfil recommendations such as (Lindenmayer et al. 2002a; Martino et al. 2005):

1. Advance and clear formulation of goals
2. Clear specification of criteria for the selection of target species
3. Extensive a priori knowledge of species selected
4. Target species approach needs to be complemented with other approaches
5. Peer review
6. Suite of species should represent a broad range of scales and habitats

7. Easy and cost effective to monitor
8. Confirm effectiveness of target species as surrogates.

Indicator species, actually, are not a tool to solve all biodiversity conservation problems; they require a diversity of approaches (Lindenmayer et al. 2002a; Roberge and Angelstam 2004). Anyway, the identification of focal species and their habitat requirements provides quantitative criteria by which to ground planning of habitat rehabilitation and reconstruction and to support ecological impact assessment, as shown in the next chapters.

2.6.3. Fragmentation and connectivity assessment

One important consequence of fragmentation is that isolation of suitable habitat patches hinders dispersal and colonization (Hanski 1994). A change in landscape connectivity can affect reproduction and mortality, for example, through allowing or limiting access to potential breeding sites. Thus, local extinction and colonization depends on patch sizes and spatial configuration, but it may be caused also by barrier effect of landscape elements, such as an infrastructure or settlement development.

For these reasons, it is important to analyze the possible flows of species dispersal and to assess the possible bottlenecks or gaps that a plan or project may involve. Thus, it is significant to analyze the spatial configuration of smaller landscape elements that may play crucial role in the movements of organisms outside habitat patches (e.g. Bélisle and St. Clair, 2001, in cited in Adriaensen et al. 2003).

Today many indices are available to evaluate a habitat spatial configuration from fractal analyses to lacunarity (Allain and Cloitre 1991). A variety of methods has been proposed for assessing habitat connectivity (e.g. Schumaker 1996; Keitt at al. 1997; With et al. 1997; Calabrese and Fagan 2004) and fragmentation (e.g. Jaeger 2000b). There are literally hundreds of such indices, often they are used without a clear statement (Farina 2001).

According to Farina (2001) these indexes can be divided in two broad categories: structural indexes and context indexes. Generally, the structural indexes deal with size and shape of the composing patches of a mosaic. The context indexes measure the spatial attributes of the different categories of patches and the overall characteristics of the mosaic *per se*. All the indexes can be applied efficiently only if a comparative action follows the measures.

Landscape metrics applied to quantify connectivity using a single value are simple to implement and require relatively little data, but appear to be too simplistic to incorporate detailed spatially explicit landscape information and its effect on species-specific (dispersal) movement (Adriaensen et al. 2003; Fall et al. 2007).

Recently, the 'least-cost' modelling has been proposed, as an approach to incorporate detailed geographical information as well as behavioural aspects in a measure for connectivity (e.g. Walker and Craighead, 1997; Villalba et al., 1998; Halpin and Bunn, 2000; Ferreras, 2001; Graham, 2001; Michels et al., 2001; Schadt et al., 2002; cited in Adriaensen, 2003). The basic idea proposed by Knaapen (Knaapen et al. 1992) and subsequently developed by others, consists of assigning to a landscape unit (grid cell) a friction value according to its facilitating/hindering effects on the considered movement process. This value is used to calculate the connectivity between a source cell and a target cell, by adding the values of all cells crossed. The method is today increasingly used, not in the least because tool boxes based on this algorithm are available in the most current GIS packages (e.g. ArcView-ArcInfo, Idrisi).

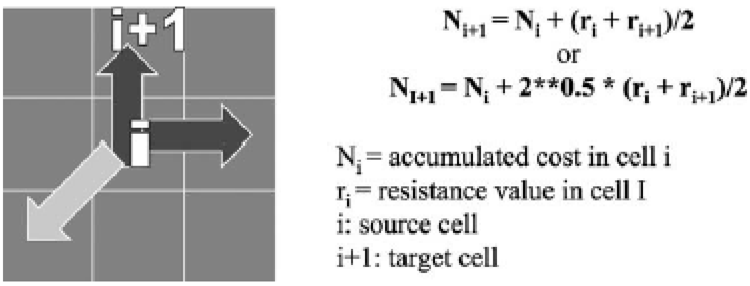


Fig. 2.11. Algorithm underlying 'least-cost' modelling (source Adriaensen et al. 2003).

Another approach applies the graph theory and concepts to landscape connectivity analysis (Minor and Urban 2008; Urban and Keitt 2001). A graph or network is a set of nodes and edges, where nodes are the individual elements (e.g. patches, habitats) within the network and edges represent connectivity between nodes (Fig. 1). Edges may be binary (connected or not) or contain additional information about the level of connectivity (i.e., flux of individuals moving between nodes; Minor & Urban 2007). Since the first applications recently a foundation of the Spatial Graph theory has been proposed, see Fall (2007) for an exhaustive presentation.

Graph-based analyses provide some advantages. Graph-based analyses help identifying key features critical for the persistence of landscape scale ecological processes (Fall et al. 2007). Identifying the importance of stepping stone habitats that could be restored to re-establish connectivity in a region, spatial graphs support the selection of habitat reserves (Pascual-Hortal and Saura 2006). Spatial graphs are shown to be very valuable in communicating the network of connections in a comprehensible and comprehensive manner, effective for decision-support (Fall et al. 2007). In addition, spatial graphs provide a method to distinguish between representation scale (that is, grid resolution) and ecological scale (that is, spatial grain relevant to ecological processes of interest), and so can support multi-scale analyses that reduce grid artefacts (Fall et al. 2007). Besides, graph theory provides a simple solution for unifying and evaluating multiple aspects of habitat connectivity, can be applied at the patch and landscape levels, and can quantify either structural or functional connectivity (Minor and Urban 2008).

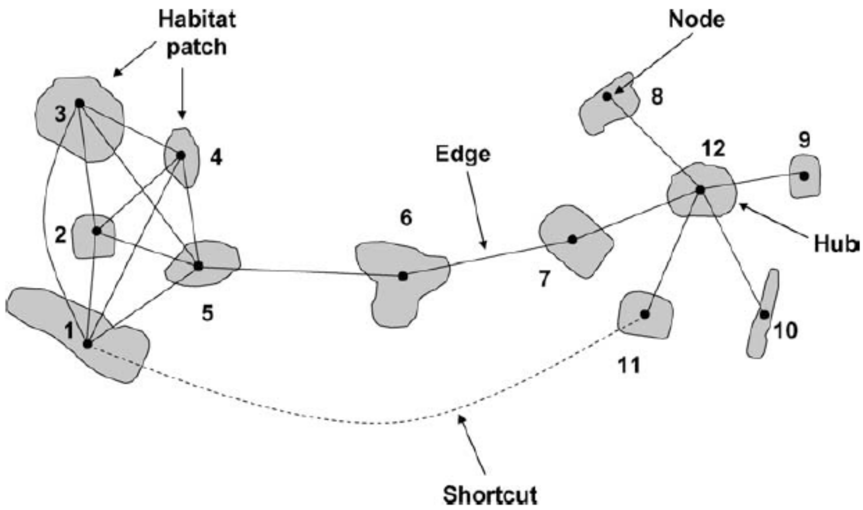


Fig. 2.12 Illustration of some spatial graph/network terms (Minor and Urban 2008).

2.6.4. Habitat network functioning assessment

Survival of species in fragmented habitats is mainly dependent on two conditions: flux of species dispersal through the matrix, that should allow the re-colonization of vacant habitats and the total amount of habitat connected, that should be large enough to support viable populations (Foppen et al. 2000; Hanski 1994; Vos and Chardon 1998). In human dominated landscapes, habitat patches in the landscape matrix are often scattered and their coverage is so low that the persistence of many species depends on the cohesion of the habitat network rather than on, simply, habitat coverage (Opdam et al. 2003). The resulting "network of populations", inhabiting the habitat (or ecosystem) network, is called a metapopulation (Verboom et al. 2001). This spatially structured population typically shows a dynamic distribution pattern in the ecosystem network (Fig. 2.13), resulting in extinctions in occupied patches, local absences and reestablishments in patches that were unoccupied by the species (Hanski 1994; Hanski 2001; Hanski and Ovaskainen 2000; Hanski and Ovaskainen 2003).

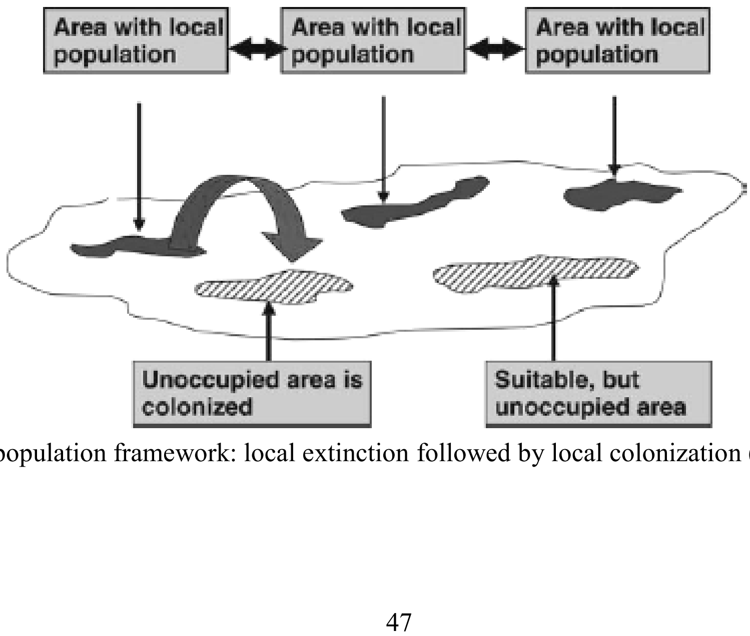


Fig. 2.13 Metapopulation framework: local extinction followed by local colonization (Opdam et al. 2003).

The evaluation of functioning for habitat networks would provide the way to integrate the evaluation of amount, quality and connectivity of habitat. In particular a habitat network can be defined “sustainable” if the flow of individuals between the patches has a minimum threshold of chance (probability) to sustain persistent metapopulation (Opdam and van den Brink 2007).

Concerning the flux of dispersal, despite its importance, relatively few studies document rates of inter-patch movement and even fewer determine population level consequences of these movements. This deficiency limits our ability to understand the dynamics of spatially structured populations and apply that knowledge to conservation efforts (Bowne and Bowers 2004). For example a disruption of landscape connectivity may not result in the immediate extinction of a species. Nevertheless, the latter could set the stage for delayed extinctions that occur years or decades later (*extinction debt*; Tilman et al. 1994, Hanski & Ovaskainen 2002). For defining a persistent population we need to be explicit on the probability by which the population survives within a certain time span.

Verboom et al. (2001), basing on review of empirical and modelling studies, proposed a operational approach by using “persistence norms”, in terms of reproductive unit (pairs of species individuals, or territories depending on the species) required by species population to have 95% of chance of survival in 100 years.

To evaluate whether the actual spatial configuration and the quality of habitats allow the persistence of a metapopulation, many spatially explicit models are developed within the Spatially Population Viability Analysis (e.g. Hanski, 1994; Foppen et al, 2000; Vos et al, 2001). The existing tools present some problems of applying in environmental assessment: too complex, difficult to generalize, dependent on data distribution.

An approach to solve these limitations: the expert-based landscape-ecological model named LARCH (Landscape ecological Analysis and Rules for the Configuration of Habitat), was developed for the Netherlands Environmental Assessment Agency (PBL) to assess the Dutch National Ecological Network (Pouwels et al. 2008). LARCH is designed as an expert system to analyze conservation policy scenarios, at national and regional scale, by visualizing the viability of metapopulation in a fragmented environment.

2.7. Conclusion

The literature reviews revealed recurring shortcomings in the impact assessment of land-use change on biodiversity. Generally, planning studies and environmental assessments focus more frequently on human-centred environmental impacts, than on broader impacts on ecological processes. The EIA/SEA applications not always seem to profit by contributions of landscape ecology field. Within planning and environmental assessment studies there is a poor attention, although increasing, on fragmentation issues. Besides, assessment applications seem often to apply ecological concepts in ambiguous manner.

Only distinguishing properly the different ecological processes allows to identify the underlying mechanisms which threaten species and ecosystems and to develop the effective strategies to counter negative impacts.
A wide literature indicates that the persistence of species populations in a landscape depends in large measure on the area and spatial configuration (connectivity) of good quality habitat (habitat functioning). Thus, theories and tools, concerning the assessment of these processes, should be applied and developed in spatial planning studies.
In particular, important concepts, especially in the framework of this study, seem to be the "focal species", as surrogate for local biodiversity, the "metapopulation" paradigm and the "spatial graphs". By them it is possible to evaluate the ecological functioning of a landscape in term of capability of supporting persistent populations. The developed methodological approach follows exactly these suggestions.

Chapter 3

A methodology for landscape ecological functioning assessment

3.1. Introduction

In the framework of the study, a landscape is defined as much "ecologically functioning" as its structure and features are able to support the persistence of present biodiversity. Here, biodiversity is represented by particular target animal species, selected for their sensitivity to habitat fragmentation and land cover change. The proposed methodology aims at assessing if and how the actual habitat configuration can sustain local populations.

Assessing the landscape structure and its ecological functioning requires multi-level analyses, in order to cover as much as possible of the ecological complexity. Thus, three levels of analysis were structured, defining different objects in a hierarchical framework. Each level presents properties emerging from the lower level, as results of spatial ecological processes. In order to provide useful indications for local planning and assessment, these levels focus on local spatial scale, considering areas from tens to thousands of hectares.

The methodology entailed four stages (Fig. 3.1), focusing on the two mentioned ecological processes: habitat potentialand functional connectivity. The first stage (A in Fig. 3.1) was dedicated to data set preparation, i.e.: land cover mapping, landscape classification and definition of spatial objects of analysis at different hierarchical levels. This stage included also the definition and characterization of the landscape elements functioning as a barrier for animal movement. The habitat potential analysis (B in Fig. 3.1) consisted in building of rule-based classification of land covers, based on habitat requirement of target species. By these rule I considered vegetation covers, area thresholds and spatial relationships according to specific dispersal distance and home range of the target species (i.e. their ecological profile).

The analysis of functional connectivity (C in Fig. 3.1) focused on the species-specific fragmentation sensitivity and it was based on spatial graph concept. In the framework of this research, a spatial graph represents functional connectivity of a landscape in terms of habitat-node and probabilistic links. The links definition depends on the barrier effect estimation of landscape elements to animal dispersal, obtained by experts' consultation.

The outputs of these stages were used for the assessment of the habitat network functioning (D in Fig. 3.1). The habitat network was considered functioning, or "sustainable", if the amount and quality of connected habitats can sustain more than one persistent (viable) species population. At this stage several thematic maps were obtained, each one for each target species. Thus, species-based evaluations were aggregated into qualitative categories, easier to communicate and to be used by planners and decision makers.

Since some works of landscape-ecology research group at ALTERRA research institute (Wageningen, The Netherlands) have inspired the present methodology, I consulted the prof. Paul Opdam group at ALTERRA. In particular, Rogier Pouwels and Astrid van Teeffelen, researchers of different groups at ALTERRA, contributed in reviewing the whole method, suggesting some improvements. In addition, prof. Santiago Saura of Lleida University (Spain) helped improving of the assessment approach for functional connectivity.
The material of this chapter is partially published in the journal *Environmental Management* (Scolozzi and Geneletti 2011), and submitted to *Journal of Environment Planning and Management*.

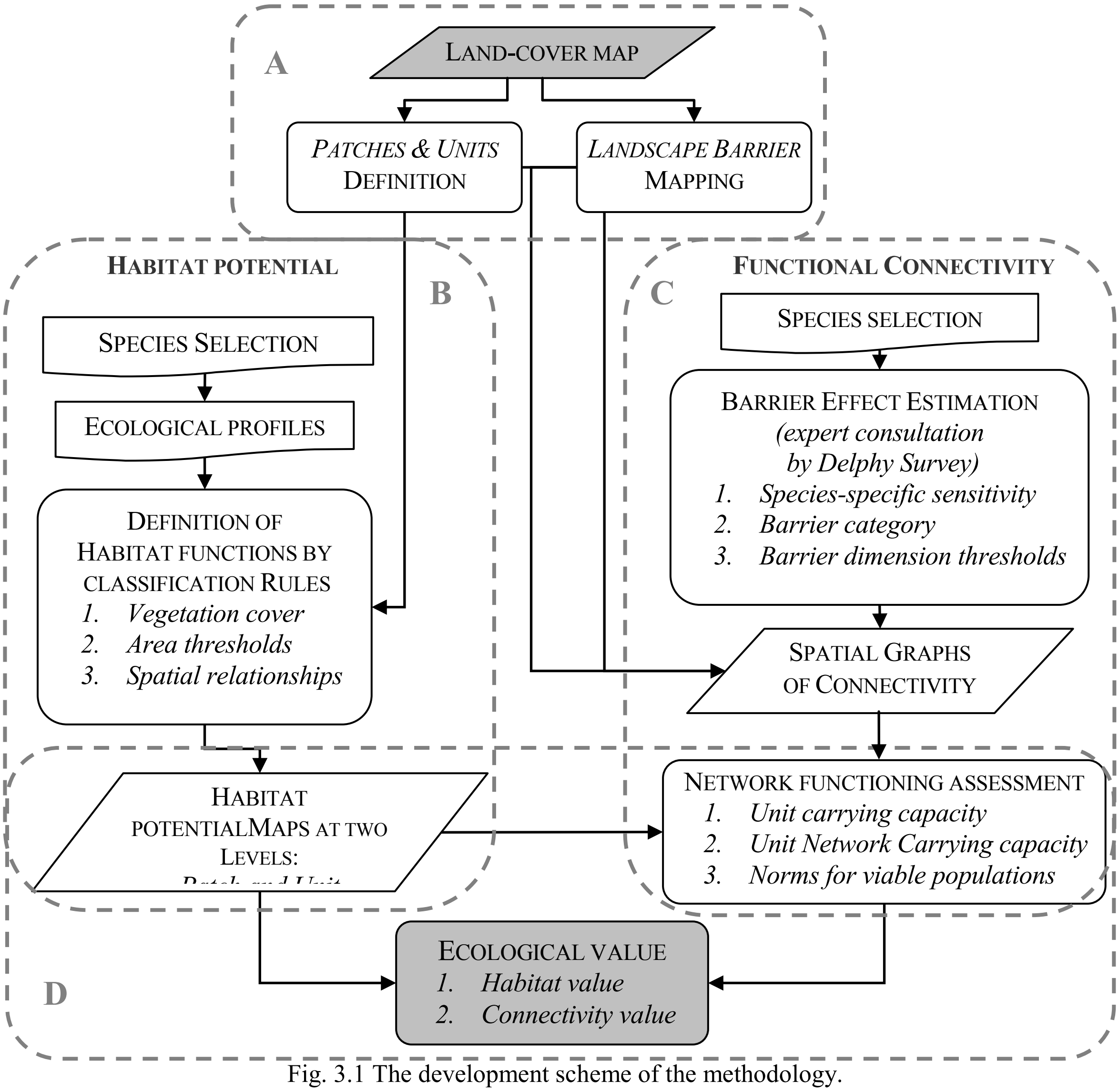


Fig. 3.1 The development scheme of the methodology.

3.2. Landscape elements within hierarchical framework

To assess potential population persistence, considering metapopulation dynamic, I applied concepts recently defined (Verboom et al. 2001a) and widely used (e.g.Chardon et al. 2003; Schadt et al. 2002) such as: Key population, Minimum key population size, Key Patch (or Key Area), Minimum key patch size, Habitat network, Sustainable network. Besides these concepts, some other were defined within the present methodology:

- *Hierarchical levels* distinguishing different levels of spatial relationships
- Landscape elements such as *Patch*, *Geographical Operational Unit* (*Unit*) and *Unit Network*,
- *Target species*, by which to assess the habitat functions provided by Patches and Units,
- *Decision rules,* for the rule-based habitat classification of Patches and Units,
- *Probability of connectivity,* based on barrier effect, defining the functional connectivity
- *Spatial Graph of functional connectivity*, representing landscape connectivity and by which to assess the functioning of Unit Network.

Landscapes are nested systems, according to Hierarchy Theory (Wu and David 2002), with ecosystems containing the levels below and being contained by the levels above. Forman (1995) noted that "a minimum of three linkages must be known. The element is linked to the: (1) encompassing element at the next higher level; (2) nearby elements at the same scale; and (3) component elements at the next lower level" (p.9). Thus, in the frame of this methodology, three hierarchical levels of spatial relationships defined different landscape ecological functions and related features (Fig. 3.2).

A *Patch* refers to an area with a homogenous vegetation cover (defined by one vegetation class) that provides habitat functions (see § 3.2.1). According to Wiens (1994), a Patch is operationally "a surface area differing from its surroundings in nature or appearance", identified by photographs interpretation and field surveys. A Patch is a polygon characterized by a vegetation ("habitat") class as defined by the third level of the EUNIS standard (European Environment Agency 2007). In general, the scale selected for the EUNIS habitat classification is that occupied by small vertebrates, large invertebrates and vascular plants, therefore it is comparable to the scale applied to the classification of vegetation in traditional phytosociology. In this study the minimum Patch area is around 50 m^2, the reference scale was likely 1: 5.000. Patches provide different habitat functions, depending on vegetation type, total area and their reciprocal relations. The Patches constitute the lower spatial scale and the first level of landscape structure.

An *Operational geographical unit (*or *Unit)* is a group of adjacent Patches delimited by natural or artificial borders, which operate as barriers to animal movement. Examples of natural barrier are: water bodies as streams, channels, lakes; morphological discontinuities as cliffs, steep hillsides (more than 100% of slope). An artificial barrier can be represented by an infrastructure (e.g. road, railway) or by an urbanized area (e.g. residential or industrial settlement). Within the Unit, the animals can move freely within and between included Patches, limited only by own dispersal capacity. The Units constitute the second hierarchical level of landscape structure (see § 3.2.2). Therefore, the Units provide different habitat functions dependent upon the configuration and characteristics of lower level of the Patches.

A *Network of connected Units* (or *Unit Network*) is a group of connected Units. The definition of "connected" depends on the species-specific barrier effect of the matrix elements between adjacent Units. To move from one Unit to another Unit animals have to pass through landscape elements, i.e. the matrix, with a probability of success. This probability is based upon the barrier effect, i.e the effectiveness in interrupting the animal moving. A panel of selected experts estimated this effect for each target species. The barrier effect was used to model the ecological spatial relationships between Units. These spatial relationships are represented by the Spatial Graph of connectivity (see § 3.3) and characterize the third hierarchical level of landscape organization.

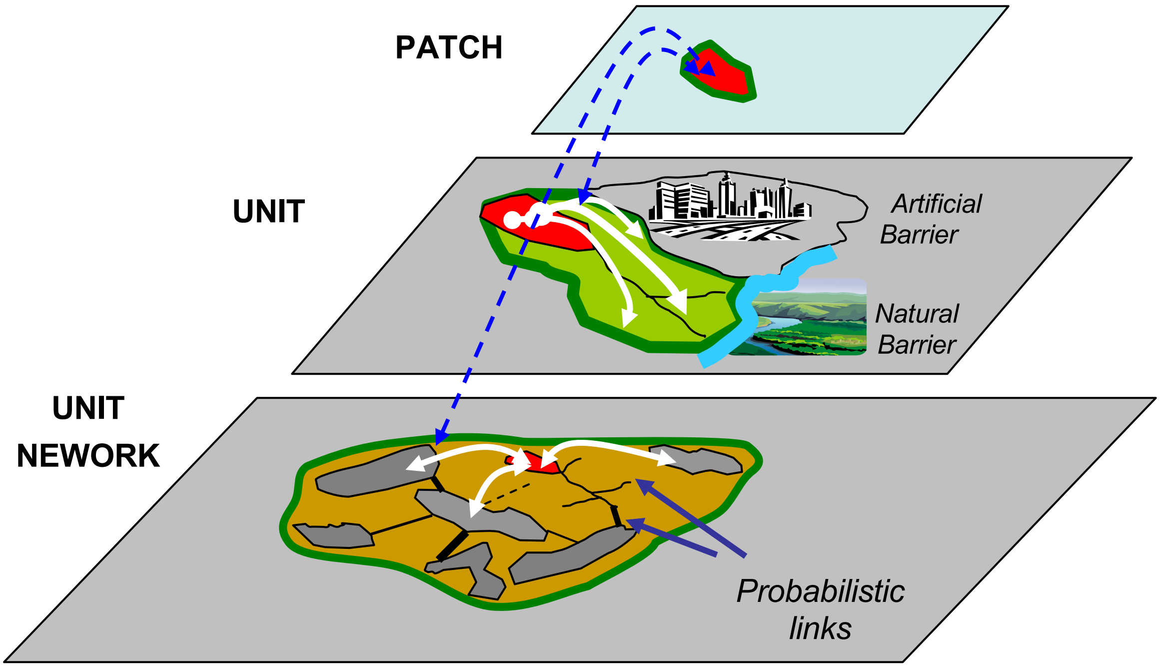


Fig. 3.2 The "spatial objects" and the hierarchical levels.

3.3. Habitat potential assessment

The assessment of habitat potential consisted in rule-based classification. The rules assign a habitat potential class to each Patch and Unit, by the species perspective. Classification outputs are habitat maps for each target species, defined at two levels of spatial organization. These results were subsequently used within the assessment for Unit Networks, then generalized in an "ecological value".

3.3.1. Target species and ecological profiles

Selection of target species refers to "focal species" concept (Lambeck 1997), aiming covering a variable set of species and habitats. This approach is more efficient in promoting minimizing extinction rate (Possingham et al. 2002).

The selection focused to main ecosystems covering the study area, namely: wetlands, rural grasslands, woodlands. Besides, the species should represent the group of small and medium-size animals (meso-fauna) such insects, amphibians, birds and mammals not carnivorous. These animals explore the landscapes within short distance, and their home ranges are comparable with the size of land-use changes planned at local scale. In particular, I referred to those species present in local protected areas at the valley floor, Biotopi Provinciali (protected provincial biotopes), focusing on areas situated under 800 m of altitude. These areas can be considered as "reference condition" for biodiversity in valley floors.

The "reference condition" concept is used in the Water Frame Directive to provide indications of "good ecological status" (2000/60/EC). Considering these areas functioning as "the best" may be questionable, but it is important to recall that these areas are often the result of historical dynamic equilibrium between human activities and ecological processes. Today these ecosystems depend on human intervention. Being ephemeral environments they would be extinguished even by a natural vegetation climax, undergoing a local biodiversity loss (Laiolo et al. 2004).

The selection of target species for the study area, according to literature indications (Lindenmayer et al. 2002a; Martino et al. 2005), is based on the following criteria:

- Present in the area, i.e. recorded in provincial biotopes within and nearby the study areas, at valley floor
- Related to one of the three habitat types: woodland, grassland and wetland.
- Selective species: referring to the spatial distribution and the spatial density, that is not too common (not selective) and not too rare (e.g. only 1-2 sites recorded), to avoid pure stochastic event and being too difficult to monitor;

- Important for biodiversity conservation, e.g.: threatened species, declining population, included in Red Lists, etc.
- Known for habitat requirements (e.g. already used as target or focal species)
- Sensitive to habitat fragmentation and to land use changes.
- With different mobility: different vagility and different dispersal range, comparable to spatial range of study area
- With a metapopulation potentially contained within the study area.

Eventually, two species for each habitat type were selected, with different sensitivity to habitat fragmentation, i.e. a flying species and a terrestrial one.
The target species provide the references used to set the habitat classification. An area provides habitat functions according “ecological profiles” of target species (Vos et al. 2001). An ecological profile includes: habitat requirements, natural density, minimum area for a *Key Patch*, minimum number of reproductive unit (RU) for a *Key Population*, minimum area for a *stepping stone*, the number of RU expected for a *stepping stone* of stepping, the home range.
In detail, the natural density, in suitable habitat, is the expected number of reproductive units (RU), i.e. number of pairs or relative territories (or families, depending of the species). This was used to define a minimum area functioning as Key Area (as hectares), basing on the Key Population (see the Annex IV). The minimum size for Key Population was founded on empirical studies and simulation models (see a review in Verboom et al., 2001). The minimum habitat area functioning as a *stepping-stone* was analogously derived from empirical studies. The relative expected population is calculated or esteemed for specific area of stepping-stone by species natural density. The home range is the maximum distance that the species daily covers from nest or refuge (e.g. in feeding activity). This distance was also considered, as a reference to define if two disjoined areas may constitute one single habitat, by species perspective.
All this information was obtained from specific literature review and expert consultation. In the case of information not available, some values were deduced from standards proposed for groups of species by Verboom et al. (2001). In some other cases, these were derived by interpretation and crossing of more than one study.

3.3.2. Habitat assessment at Patch level

Habitat assessment was defined in qualitative terms, rather than using a numeric scale. This classification explicitly refers to different habitat functions, following the approach of Löfvenhaft et al. (2004). The proposed approach is based on vegetation cover as in other studies (e.g. Boitani et al. 2002) but it considers further factors such as: area thresholds, spatial relationships, hierarchical levels. In effect, a land cover is not sufficient to define

habitat functions, also the size of the areas should be considered. One Patch may fulfil different habitat requirements of the species depending on area size. For example, a wooded area may provide refuge sites for interior woodland species if large enough, or only a feeding site if smaller, or simply a corridor towards other site. In detail, the area thresholds referred to a minimum habitat area that may function as stepping stones.
For Patch, five qualitative classes of habitat potential were distinguished:

- *Breeding Patch*: areas in which is assumed that species can find refuge or nesting sites, or breeding sites and food resources. These are the most suitable areas, sustaining a stable presence of a small group. They can play the role of stepping stone within a network and sustain a key population if sufficiently large.
- *Survival Patch*: areas with the same characteristics as above mentioned but smaller, or with different vegetation cover. They are suitable for limited habitat functions e.g. only feeding sites. In these areas it is likely to find a temporary presence or a stable presence of fewer individuals.
- *Dispersal Patch*: areas suitable only for the dispersion of individuals, with poor resources and no nesting or refuge sites, for which it is hypothesized only a temporary presence.
- *Unsuitable Patch*: areas not suitable for any habitat functions.
- *Hostile Patch*: area in which the species could be injured by direct threats (e.g. casualties by road traffic).

The classification of each Patch was tailored for each target species. The classification rules have an *if-then* form, as shown in Tab. 3.1 and reported in the Annex III, with spatial and non-spatial conditions. The conditional cases were based on vegetation classes, according to EUNIS standard, and on total area of nearby covers listed in the same conditional case.

Tab. 3.1. Example of rules for habitat potentialclassification.

IF – Conditions	**THEN – Habitat potential category**
(“Sparsely wooded grasslands with trees/bushes” OR “mesic and dry grassland” OR …) AND (Area >5 ha)	Breeding Patch
(“Sparsely wooded grasslands with trees/bushes” OR “mesic and dry grassland” OR …) AND (Area >2 ha and <5 ha) OR (“Anthropogenic herb stands”) AND (Area > 2 ha)	Survival Patch
(“Sparsely wooded grasslands with trees/bushes” OR “mesic and dry grassland” OR …) AND (Area< 2 ha) OR (“Anthropogenic herb stands”) AND (Area < 2 ha)	Dispersal Patch
“Highly artificial man-made waters”	Unsuitable Patch
“Transport networks”	Hostile Patch

In practice, for each target species, the habitat potentialclassification entails two steps: first, the study area is classified according to the vegetation mosaics, i.e. vegetation assemblages meaningful for the species of concern, assigning the habitat categories. Then, the classified Patches were dissolved (within each Unit), forming polygons representing Patch clusters. These clusters were classified by their total area according to the area thresholds, defined in conditional cases (Tab. 3.1.

The query sets was structured within a geodatabase developed using *PostGis*, the spatial database extension for *PostgreSQL* (http://www.refractions.net). The geodatabase allows updating quickly the habitat classification, whenever a land-use change affects a Patch. All the information elaborated for above levels (Patch clusters, Units and Unit Networks, as shown below) were stored for each Patch-polygon. Although approximately, it provides a simulation of habitat potentials within a study area, correspondingly it can simulate how land cover modification may affect a landscape ecological function.

It should be kept in mind that these thresholds and rule sets define conditions for species occurrence but they do not intend to model the spatial distribution of species population. These occurrence conditions should be considered only as minimum necessary but not sufficient conditions.

3.3.3. Habitat potentialat Unit level

At Unit level, four similar classes were defined:

- *Breeding Unit*: areas that include a mosaic of nearby Breeding and Survival Patches. These areas may constitute a Key Area, with a carrying capacity for a Key Population.
- *Survival Unit*: mosaics as described above but smaller or without Breeding Patches, supporting a local population, but not a Key Population, they may provide "stepping stone" function.
- *Dispersal Unit*: a mosaic of Survival and Dispersal Patches that covers more than 60% of total Unit area. This value is founded on percolation threshold (Farina 2001), that means minimum ratio habitat/matrix of a region that theoretically allows a species, moving only through the habitat, to pass through the region.
- *Unsuitable Unit*: areas without meaningful habitat functions for the species of concern.

The assignment of these categories is based on the lower-level Patch classification, distances between Patches and area thresholds. The distance is species-specific and related to the home range of species. The area thresholds refer to an area working as stepping stones or Key Area for defined species. In this case these may support sub-populations and their relationships, rather than individuals or little groups as above.

It is possible to estimate a number of individuals potentially sustained by a Breeding or Survival area, according to natural density of species. So, the carrying capacity for the *i*-Unit (UCC) may be calculated, in terms of reproductive units (RU) of the species *j*, by the following equation [1]:

$$[1]\ Ucc_{j-species}(i) = \sum_{l \in S(Unit_i)} a_l \times d(S,j) + \sum_{h \in B(Unit_i)} a_h \times d(B,j)$$

Where: a_l is the area (as hectare) of patch belonging to the group of Survival Patches included in i-Unit, i.e. $S(Unit_i)$; a_h *is* the area (as hectare) of patch belonging to the group of Breeding Patches included within i-Unit, i.e. $B(Unit_i)$; $d(S,j)$ the expected density of the species *j* in Survival patches (as RU/ha), $d(B,j)$ is the expected density of the species *j* in Breeding Patches.
UCC means the capability of an area to sustain a defined number of species individuals. The difference in density between a Breeding Patch and a Survival Patch depends on different assumptions about habitat functioning.

3.4. Functional connectivity assessment

For metapopulation persistence the connectivity may be more important than a total amount of small-patch ecosystems (Fahrig and Merriam 1985). The barriers to species movement are crucial element affecting the ecosystem connectivity, especially in contexts of Alpine valley floor. In terms of matrix structure, both the permeability of the patches themselves and the permeability of the boundaries between patches, determine the degree of impact that matrix has on species habitat. The obstacles, interrupting an ecosystem network, could be constituted by landscape elements or by their borders. For these reasons is important to consider all landscape elements that can form a barrier to terrestrial animal movement.
The basic idea for the evaluation of functional connectivity is the estimation of the barrier effect of landscape elements to species dispersal. The barrier effect, as the species-specific (functional) connectivity, affects the probability of success of species movement between habitat fragments. The barrier effect was estimated by experts engaged in a Delphi survey, in terms of probability of success of a species in passing the barrier. The results of Delphi survey were first used to draw the "Graph of functional connectivity" and the "Fragmentation 3D map".

3.4.1. Selection of target species

In this particular case, the selection of target species aims at covering a range of fragmentation sensitivity and an assortment of habitats present in the study area. Precisely, the selection followed criteria as: presence within study area, relation with the main habitat

types covering the study area, different vagility and dispersal distance, available information on their home range and dispersal distance.
Dispersal distance is the distance that species usually tread during migration or seasonal moving (e.g. breeding period). Home range is the range of the area used daily. Home range and dispersal distance criteria are also used to select species with populations potentially included by the study area. The species set should include the species already considered for habitat analysis.

3.4.2. Barrier characterization

The barrier characterization was meant to represent all possible landscape elements that could work as a barrier for animal dispersal. This entailed identifying a feature set of general cases, to be subsequentely assessed by experts and constructed in collaboration with experts. This set included border elements as walls or fences and similar, linear elements as streams or roads and superficial elements as urban areas or industrial areas.
For each element category, more size thresholds were considered to differentiate the barrier effects on the target species. The definition of the thresholds aimed at setting a effectiveness gradient for the barriers. The list, as proposed in questionnaire for Delphi survey is reported below (Tab. 3.2).

Coding		Barrier elements	Dormouse
mur3070	Border elements	wall (or fence, o similar) 0.3- 0.7 m	
mur7015		wall 0.7- 1.5 m	
mur>15		wall >1.5 m	
acq<30		Body of water, depth <0.30 m	
acqlen>30		Body of water, depth >0.30 m	
acqvel>30		Running waters, depht >0.30 m	
	Infrastructures		
strd0	Supposable traffic <50 vehicle /day	Minor/Rural/Forestry paved roads	
strd1	<500 vehicle /day	Secondary road, one lane, or 2 lanes with very low traffic	
strd2	<5000 vehicle /day	Loca/urban road, 2 lanes	
strd2+	>5000 vehicle /day	National road, beltway, highway, more than 2 lanes	
	Areas		
parc100	Referring to relatively small areas: a hypothetical 100 m size square	Urban park, public garden	
udens100		Industrial areas	
udens100		Dense Residential areas (vegetation cover < 30%)	
urado100		Sparse Residential areas (vegetation cover > 30%)	
parc1000	Referring to relatively large areas: a hypothetical 1000m size square	Urban park, public garden	
udens1000		Industrial areas	
udens1000		Dense Residential areas (vegetation cover < 30%)	
urado1000		Sparse Residential areas (vegetation cover > 30%)	

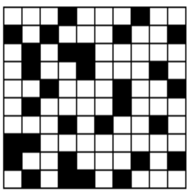
Tab. 3.2 Barrier elements list (extracted from questionnaire)

Additional notes were reported to help filling in the questionnaire. The notes add details describing barrier cases and the scenarios in which the species may find obstacle. In particular, water bodies were distinguished by depth and flow speed and distance between the banks. The cases with distance between the banks above threshold of 10 m were automatically considered as obstacle impossible to be passed by all the species, except for the amphibians (as Ediblefrog). These species anyhow avoid offshore waters of lakes (Ficetola and De Bernardi 2004a; Löfvenhaft et al. 2004), hence cases of distance from between banks (or shores) exceeds 150 m were assumed providing obstacles also for amphibians. Besides, their occurrence in lakes and ponds is highly limited by the fish presence.

Concerning the waters depth, the water bodies with an average depth more than 30 cm were distinguished in two flowing speed categories: from 0 to 0.5 m/sand to 1.5 m/s. This distinction was set to differentiate swimming capability of the target species. These thresholds refer to distinguish between the habitat for Cyprinidae family and for Salmonidae family fishes. The first group of fishes, in fact, inhabits usually standing or slowly flowing waters. Rivers with deeper water (>30 cm depth) or higher water flowing speed (> 1.5 m/s) were automatically considered as utter obstacle.

The roads were distinguished by category and supposable traffic flow. The proposed simplification allowed setting apart different barrier effects, despite lacking data about vehicle traffic flows.

Concerning the land surfaces, a more complex approach was proposed. Rather than asking the experts to define impendence values associated to a land cover (like as in e.g. Adriaensen et al. 2003), two kinds of scenarios were suggested, in which animal have to go across different extents of hostile areas (matrix). The first scenario involves the passing through a small virtual square of landscape, having sides of 100 m. The second scenario entails the passing through a wider square. In addition, for each scenario two densities of vegetation/artificial surfaces are distinguished by a cover ratio threshold of 30%. In order to suggest the experts a representation of 30% vegetation cover two virtual binary landscapes were included in the questionnaire. These figures represent a random pattern of black (patch) e white (matrix) cells following a 30/100 ratio.



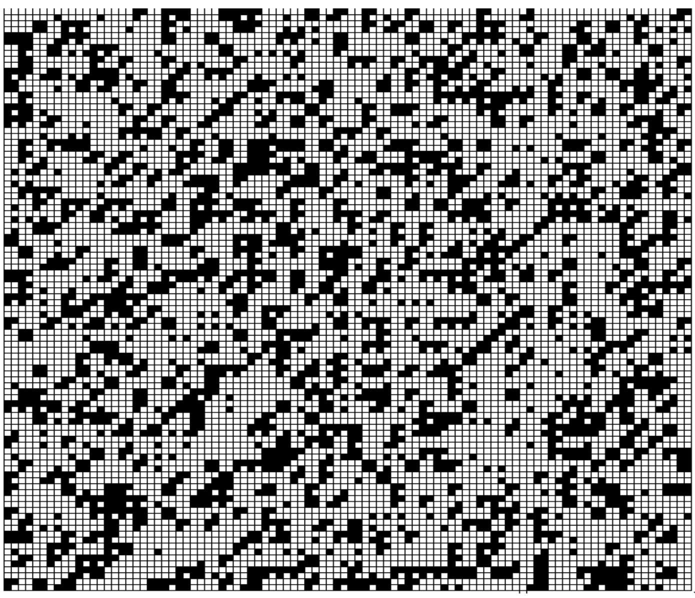


Fig. 3.3 Virtual random landscapes, with 30% of black (vegetation) cover. The second has a ten times bigger side with the same cover proportion (here the proportion are not respected).

3.4.3. Barrier effect estimation by Delphi survey

The barrier effect estimation was obtained by means of a widely used method in literature: the Delphi survey (e.g. MacMillan and Marshall 2006). The Delphi survey is chosen as being a useful tool to get reliable information when field surveys or data gathering are not possible, or for that case in which the information asked is too complex to be easily attained.

To prevent potential misunderstandings and ambiguity in probabilistic evaluations, terms as defined by IPCC (IPPC, 2001: The Scientific Basis; cf. footnote nr. 7 of the Summary for Policy Makers) were proposed (Tab. 3.3). Correspondingly, the estimated barrier effect, assessed in terms of probability of preventing animal dispersal, was converted in "probability of connection" from an Unit i to an Unit j as the complementary value to 1 of probabilistic barrier effect (last column of Tab. 3.3).

For example, a landscape element was judged being "very likely" a barrier for a defined species means that the barrier is effective with "90–99% chance", in other words, it allows, for a defined species, an average probability of connection of 0.05, out of an interval [0,1].

In few cases, with undoubted effective barrier (e.g. tall concrete wall between double lanes of a fenced road) this probability was set to 0.0.

Tab. 3.3 Probabilistic terms as verbal expressions, % of chance and fraction of chance.

Verbal expression	Chance (per cent)	Chance (fraction)	Coding [a]	Prob. of Barrier Effect [0,1]	Probability of Connection [0,1] [b]
Very likely	90–99% chance that the result is true	≥ 9 out of 10 and ≤ 99 out of 100	5	0.95	0.05
Likely	66–90% chance that the result is true	≥ 2 out of 3 and ≤ 9 out of 10	4	0.78	0.22
Medium likelihood	33–66% chance that the result is true	between 1 and 2 out of 3	3	0.50	0.50
Unlikely	10–33% chance that the result is true	≤ 1 out of 3 and ≥ 1 out of 10	2	0.22	0.78
Very unlikely	1–10% chance that the result is true	≤ 1 out of 10 and ≥ 1 out of 100	1	0.05	0.05

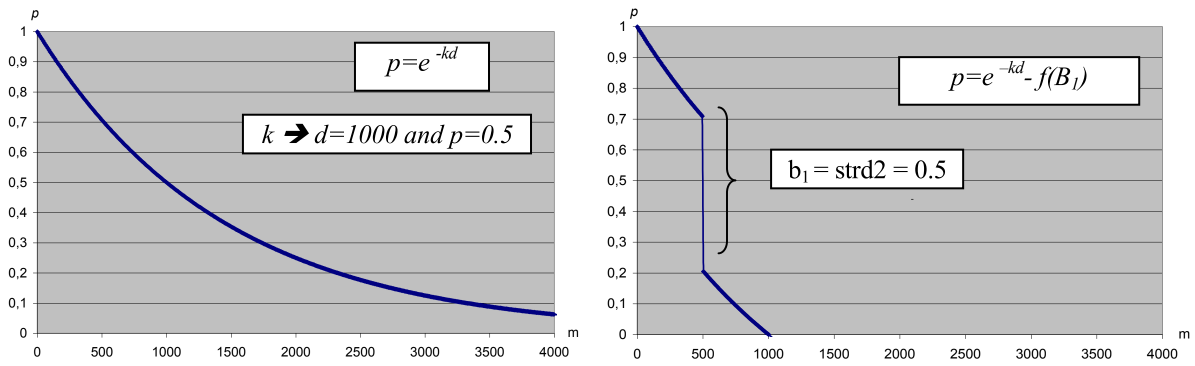
a: Code used in questionnaire, see tab. 13; b: complementary to 1 of barrier effect.

3.4.4. Graph of functional connectivity

Besides the barrier effect, the assessment of connectivity takes into account the distance between habitat fragments (Units). The distance between habitats is embodied in exponential function [1], commonly used (Pascual-Hortal and Saura 2006). In the original equation, the variable k sets the probability p equal to 0.5 at the distance of species home range. I propose a modified version [2] in which a second term expresses the barrier effect; it reduces the *p* values by the estimated probabilistic barrier effect.

$$[1]\ p_{ij} = e^{-kd(i,j)} \qquad [2]\ p_{ij} = e^{-kd(i,j)} - f_{ij}(B)$$

Where *p* is the probability of connection, *d(i,j)* is the distance between *i* and *j* habitat patches (in our case Units), *k* is the species-specific coefficient.
This calculation is performed for each pair of adjacent Unit and repeated for each target species. In the case that more than one barrier are between Units, the overall barrier effect is calculated as summation of barrier effect, i.e. as product of each probability. A maximum of three different barriers are considered, assuming that more than three barriers constitute very likely an insurmountable obstacle.
As example, a function fitted for hedgehog home range (1000m) and a barrier effect on its dispersal due to a two lane road is shown in **Errore. L'origine riferimento non è stata trovata.**. This barrier impede the hedgehog dispersal in 50% of cases.



c

The connectivity of whole network of habitats is measured by the Probability of Connectivity index. The PC index (Pascual-Hortal and Saura 2006; Pascual-Hortal and Saura 2007), defines the probability that two animals randomly placed within the landscape fall into habitat areas that are reachable from each other (interconnected). Given a set of n habitat patches (a_{ij}) and the connections (p_{ij}) among them, the PC index is calculated through the following function [3]:

$$[3] \qquad PC = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} a_i a_j p_{ij}^{*}}{A_L^2}$$

Where a_i and a_j are the areas of the habitat patches *i* and *j* (in our case Units), A_L is the total landscape area (area of the study region, including both habitat and non-habitat patches), p^*_{ij} is defined as the maximum product probability of all possible paths between patches i and j (including single-step paths).

By PC index it is possible to define the relative "importance" of one habitat within the network (Pascual-Hortal and Saura 2007), using the equation [4]:

$$[4]\ dI(\%) = \frac{I - I'}{I} \times 100$$

Where *I* is the PC index value when habitat element is present in the landscape and *I'* is the index value after removal of that landscape element (e.g. habitat loss). This represents the relative contribution to overall landscape connectivity of each individual Unit-node. According with Saura and Pascual-Hortal (2007) conservation efforts should concentrate in protecting those habitats with higher dI.

All this information is represented and summed up in a spatial graph (Fig. 3.4), one for each target species. The habitat-nodes represent the habitat areas (Unit or Patches depending on the detail of analysis). The width of the links is proportional to p_{ij} and node size is proportional to the importance of habitat areas within the network.

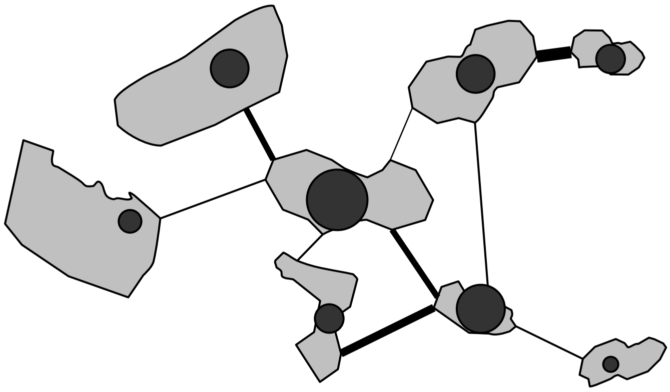


Fig. 3.4. Example of spatial graph of functional connectivity.

3.4.5. Unit Network functioning

The connectivity indices provide numerical values, for which it is difficult to define ecologically meaningful thresholds. Even though they may show impacts on connectivity by a spatial plan or project, they do not provide clear insights about their impact on local biodiversity. For these reasons, the methodology involves the evaluation of the habitat network functioning in terms of capability of sustaining local viable populations.

In detail, the assessment of habitat network functioning entails three steps:

1. Definition of "connected" Units (forming the Unit Network),
2. Calculation of Network Carrying Capacity (NCC),
3. Classification by comparison of NCC with persistence norms.

The spatial graph represents all the linkages between Units. I used a probability of connection of 0.5 to set apart the networks of “connected” Unit, dividing the spatial graph components (Bodin and Norberg 2007), or sub-network, as in the example in Fig. 3.6.
All “connected” Units, belonging to a single graph component, provide a Network Carrying Capacity (NCC), as summation of each Unit carrying capacity (UCC), for a the species *s*, as follows [5].

$$Ncc(s) = \sum_{i \in UnitNet_{(0.5)}} Ucc(s)_i \quad [5]$$

The NCC values are compared with the “persistence norms” (Tab. 3.4) defined for each target species, i.e. different norms are considered for different habitat networks. The network functioning is evaluated by three categories according to the following rules:

Rules	Extinction chance
IF $Ncc_s / norm_s \leq 1$ **THEN** “Not sustainable”	likely probable
IF $1 < Ncc_s / norm_s < 3$ **THEN** “Fairly sustainable”	≈ 5% in 100 years
IF $Ncc_{is} / norm_s \geq 3$ **THEN** “Viably sustainable	< 2% in 100 years

The “persistence norms” have been defined by Verboom et al. (2001), reviewing metapopulation simulation models and empirical studies, as the minimum number of RU, of a certain species, that an ecosystem network should support to sustain effectively a viable metapopulation. In particular, two types of ecosystem networks are distinguished: 1) networks with a minimum Viable Population (MVP) or with a Key Area, 2) networks without a MVP or Key area. Each type of network must have a sufficient amount of habitable area, for a viable population of a species to occur.

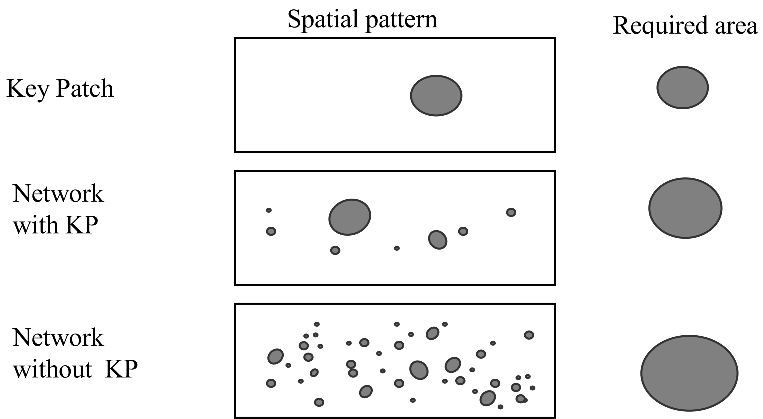


Fig. 3.5 Required habitable area for different habitat networks (modified from Verboom, 2001).

This amount (then, the relative norm) differ for the two network types (Fig. 3.5), because in a network without Key area the local populations are more dependent on dispersal, then more individuals are required to move from temporary "source" habitats (in order to offset the casualties during dispersal).

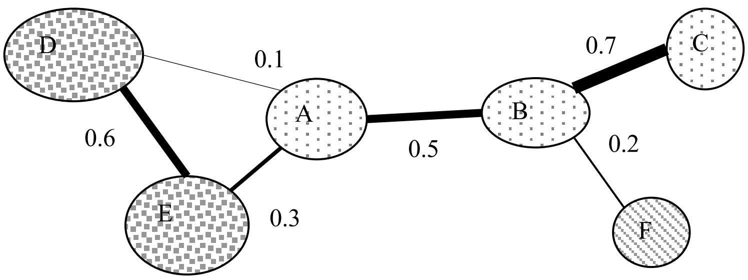
Tab. 3.4 Norms for viable population (grey: the used values for study area).

Species (group)	Key Population	Network with KP	Network without KP
Long.lived/large Vertebrate (e.g. mammals as badger)[a]	20	80	120
Middle-long lived/medium sized vertebrates (e.g. birds as nuthatch)[a]	40	120	200
Short-lived/small vertebrates (e.g. birds as sedge warbler) [a]	100	150	200
Natterjack toad [b]	200	500	800
Amphibians [b]	500	750	1000
Hazel dormouse [c]	100	150	200
Hedgehog [c]	40	120	200
Ediblefrog [c]	500	750	1000

a: Verboom et al ,2001; b: Ottburg et al., 2007; c: norms adjusted in comparison of Verboom et al., 2001, after expert consultation (Pouwels).

The factor 3 in Ncc/norm ratio aims to guarantee a certain degree of robustness under the highly uncertain estimation of the RU. In a similar study, at national and regional scale, it was used a factor 5 (Ottburg et al. 2007); the populations, for those cases, are really isolated from outside dispersal contributions. As a "fairly sustainable" network may sustain a viable metapopulation, with an extinction chance of 5% in 100 years, it is assumed that a viably sustainable network may accommodate a population with a probability to survive over 98% in a period of 100 years.

As example to explain these calculations, a virtual ecosystem network for Ediblefrog is assessed as follows.



Unit	UCC	Links	P_{ij}
A	345	AB	0.5
B	570	AD	0.1
C	220	AE	0.3
D	1800	BC	0.7
E	120	BF	0.2
F	430	DE	0.2

Fig. 3.6 Example of habitat network and habitat sub-network.

The network is composed of six nodes and six links (bidirectional). By the threshold 0.5, this network is decomposed in three graph components (Fig. 3.6), defined by the threshold of 0.5 in connection probability: A-B-C, D-E, F. The wider component includes a Unit supporting a key population (B, 570 > 500 RU). Thus, the sub-graphs' functioning is defined as follows:

$Ncc_{ABC} = 345 + 570 + 220 = 1135$ ➔ "Fairly sustainable"

$Ncc_{DE} = 1800 + 120 = 140$ ➔ "Viably sustainable"

$Ncc_{F} = 430$ ➔ "Not sustainable"

3.5. Ecological value classification

3.5.1. Integration of specie-based assessments

The previous analyses provide quantitative and qualitative results. It should be kept in mind that rule-based habitat classification and network functioning evaluation are species-specific and species-oriented. All the results were defined in ecological terms as "habitat network supporting viable metapopulation" or "Breeding Patch for species *a*". Though clear to ecologists, these terms may be difficult to be directly used by decision makers or by other stakeholders involved in a planning process. Communication concerning environmental assessments should facilitate debate among experts and decision makers, since "territorial planning requires scientific data but ultimately depends on the expression of human values" (Theobald et al. 2000). In particular, the biodiversity conservation itself is a cultural and social activity, guided by science but done by the public (Opdam et al. 2003).

Considering that, a qualitative multi-attribute evaluation is proposed as a secondary part of the methodology. This model is meant to provide to planners value-based information. The final result of the evaluation is the assignment to each Patch of an *Ecological value*. This is attributed according the *Habitat value* and the *Connectivity value*. These values are derived from the species-oriented results aggregated in a bottom-up way according to defined rule sets. In fact, the evaluation approach consists in rule sets structured in a hierarchical framework that follows the conceptual scheme presented at the beginning of this chapter. The rule structure takes the shape of a decision tree (

Tab. 3.5), in which each ramification represents different level attribute and aggregation steps.

In detail, the decision rules have "if-then" form; i.e. a rule defines the value of an attribute according to the importance of or priority among lower-level attributes. Three levels of aggregation are defined for the *Habitat value*. The first aggregation involves a comparison within the target species related to the same habitat type. This aggregation follows a "maximum rule", in which the final attribute is defined by the best (maximum) case of lower-level attributes.

The second aggregation entailed a comparison between habitats, resulted by the previous aggregation, and the definiton of a "general" habitat value at Patch level according to the same maximum rule. These two aggregation were performed for both Patch level and Unit level.

Applying the maximum rule means, in this case, that different habitat types have the same importance. The aggregation may attribute more importance to one or two habitat types, for example to those more vulnerable and rare. In an ideal application of the methodology, these rules could be discussed with local experts and shared with planners.

Attribute	Scale
Ecological value	***Very high***; ***High***; Medium; Poor; **Negligible**
├ **Habitat value**	***High***; ***Medium***; Low; **Negligible**
├ **Patch habitat value**	***High***; ***Medium***; Low; **Negligible**
├ **Wetland communities**	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
├ Species a	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
└ Species b	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
├ **Grassland communities**	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
├ Species c	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
└ Species d	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
└ **Woodland communities**	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
├ Species e	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
└ Species f	***Breeding***; ***Survival***; Dispersal; **Unsuitable**; **Hostile**
└ **Unit habitat value**	***High***; ***Medium***; Low; **Negligible**
├ **Wetland communities**	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
├ Species a	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
└ Species b	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
├ **Grassland communities**	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
├ Species c	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
└ Species d	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
└ **Woodland communities**	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
├ Species e	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
└ Species f	***Breeding***; ***Survival***; Dispersal; **Unsuitable**
└ **Connectivity value**	***High***; ***Medium***; Low; **Negligible**
├ Wetland Network functioning	**Not sustainable**; Fairly sustainable; ***Strongly sustainable***
├ Grassland Network functioning	**Not sustainable**; Fairly sustainable; ***Strongly sustainable***
└ Woodland Network functioning	**Not sustainable**; Fairly sustainable; ***Strongly sustainable***

Tab. 3.5 The decision tree, showing the attributes and the relative qualitative scales. The colours indicate "good" value (green), "neutral" value and "bad" value (red).

The third level of aggregation, between Units and Patches, follows the rules presented below Tab. 3.6. These rules assign to a Patch a value basing on the local habitat quality (Patch level) and on the nearby habitat quality (Unit level). In particular, these rules assign more importance to the Patches.

	Patch habitat value	Unit habitat value	Habitat value
1	***high***	***high***	***high***
2	***high***	***medium***	***high***
3	***high***	low	***medium***
4	***high***	**negligible**	***medium***
5	***medium***	***high***	***high***
6	***medium***	***medium***	***medium***
7	***medium***	low	***medium***
8	***medium***	**negligible**	low
9	low	***high***	***medium***
10	low	***medium***	low
11	low	low	**negligible**
12	low	**negligible**	**negligible**
13	**negligible**	***high***	**negligible**
14	**negligible**	***medium***	**negligible**
15	**negligible**	low	**negligible**
16	**negligible**	**negligible**	**negligible**

Tab. 3.6 Aggregation of Habitat values at Patch and Unit level into a general Habitat value.

This means, for example, that a *Survival Patch* within a *Dispersal Unit* (rule 7 in Tab. 3.6) is considered more important than a *Dispersal Patch* within a *Survival Unit* (rule 10 in Tab.

3.6). The first case represents an area that may sustain, at least, a stable presence of a little group of individuals (Survival Patch), with a low nearby habitat quality (Dispersal Unit). The second case represents an area not really functioning as habitat, although located in a functional context (Survival Unit). To assign an equal importance the rules should be completely symmetric (for example, since the rule 7 establishes "medium" the rule 10 should also establish "medium").

Concerning the connectivity, a *Connectivity value* is derived from habitat network evaluations performed for the single target species associated to one habitat type. This aggregation is based a particular kind of "maximum rule" considering two terms at the same time, i.e. the attribute Y is defined according to the two best values for $X_{1,}$ X_2, X_3. This more complex approach is justified considering that Units may include more than one habitat type. Thus, the highest values are attributed to Unit network functioning for more than one target species. This rule could be represented briefly using a numerical code for the qualitative classes, saving to quote the 27 rules for 27 possible combinations. Then, assuming "viably sustainable"=3, "fairly sustainable"=1, "not sustainable"=0 and summing the three contributions, the Connectivity value is defined by following rules:

Sum of habitat network values ➔	Connectivity value
≥ 4	*High*
= 3	*Medium*
= 2	*Low*
= 1 or 0	*Negligible*

"High" means that the Unit, including the Patch in question, belongs to a Unit network at least "viably sustainable" for one species community and "fairly sustainable" for one other community (i.e. 3+1). We expect that an impact on this Patch (then on this Unit), could disrupt a metapopulation dynamics and increases the probability of a local extinction. "Medium" means that the Unit network is "fairly sustainable" for all species communities (i.d. 1+1+1), otherwise "viably sustainable" for only one (e.g. 3+0+0). "Low" indicates a Unit network "fairly sustainable" for two species communities (e.g. 1+1+0). "Negligible" means that the Unit network is "fairly sustainable" for only one species community (e.g. 1+0+0) or "not sustainable" at all (i.e. 0+0+0).

Finally, the *Ecological value* is obtained by aggregating *Habitat value* and *Connectivity value* according to *value* according to the rules shown in the matrix below (

Tab. 3.7). These rules assume that two Patches with the same "inner" properties with, for instance, the same vegetation structure and composition, have different ecological values depending on the nearby habitat quality and the connectivity of habitat network to which they belong.

Tab. 3.7 If-then rules for the final Ecological value.

Connectivity / Habitat	High	Medium	Low	Negligible
High	Very high	Very high	High	High
Medium	Very high	High	Medium	Medium
Low	High	Medium	Low	Negligible
Negligible	Medium	Low	Negligible	Negligible

The matrix of the rules is not symmetrical, the rules definition assign a slightly higher priority to habitat quality. This is because from the biodiversity conservation perspective the functioning of the areas is more important. High quality areas provide important ecological processes and may contribute to conserve more levels of biodiversity. On the contrary, in this framework, the connectivity is a crucial process mainly for the terrestrial fauna. Anyhow, other experts can propose different assumptions within the application framework. These may entail different priorities and the building of different decision rules. In the following chapter, the results based on different assumption are shown.

3.5.2. Indications for environmental planning and assessment

The evaluation of habitat potential and connectivity provides an “ecological characterization” of an area, in other words it define a possible “ecological role” of each site within landscape pattern. Thus, the areas with high connectivity and habitat value are likely to provide the *sources* of local biodiversity. Other areas with lower connectivity value (e.g. isolated habitat) may provide *stepping stones*. Conversely, other areas with low habitat value but well connected may provide *ecological corridors*. This ecological characterization may identify, at the beginning of planning process, the actual “vocation” of the areas. Through such ecological characterization it is possible to obtain operational indications for the planning, at local scale, and for environmental assessment.

The habitat/connectivity matrix is translated in a kind of checklist for the impact assessment on ecological structure of a landscape (Tab. 3.8). The checklist is meant to guide further analyses concerning two type of impact according with the different ecological role of the site: habitat loss and habitat fragmentation. The assumption is that different impacts have different importance depending on the actual ecological role of the site affected. Although these impacts are often correlated, it might be useful distinguishing them in order to depict different strategies for compensation or mitigation.

The same habitat/connectivity matrix may also support the design of planning strategy, providing draft indications for spatial planning as well as for habitat restoration, or compensation (Tab. 3.8). In the case of high quality habitat areas, which are also well connected, the plan may involve “preservation”. In the case of high quality but fragmented habitats, the plan may consider “de-fragmentation” actions, as constructing of a tunnel or a crossing for the wildlife. In the case of low quality habitat but effectively connected, the “restoration” or new habitat creation could be indicated. In fact, less functioning habitat may be still potentially valuable if they can provide important conduits for dispersal in regions where landscape structure is already fragmented.
Anyhow, this kind of indication should be seen as an introductory support to a strategy development, i.e. preparatory analysis that can indicate which strategy and where it might be better used

3.6. Conclusion

This chapter proposes a methodological approach for carrying out the assessment of landscape ecological functioning for what concerns the habitat potentialand functional connectivity. The approach is not meant to comprehensively model ecological processes at landscape scale, neither to model species distribution within metapopulation spatial pattern. Rather, it aims at setting concepts and proposing some basic analyses that can support the assessment of consequences on biodiversity due to land-use changes, then, accordingly can help environmental impact assessment and spatial planning.
The literature review highlighted the limits of many landscape indices in providing operational indications for planning, and in characterizing ecological relevance of each area in a landscape. The proposed approach means to contribute to overcome these limits, by providing a methodology that requires few basic data and has a scientific background.
In particular, the proposed approach to habitat potentialassessment allows a quantitatively account of local biodiversity assets, i.e. carrying capacity for target species in terms of number of reproductive units. By basing the assessment on spatial rules/queries, managed by a geodatabase, the approach models spatial attributes of landscape features within a dynamic perspective. This facilitates a routinely application of the procedure.
The assessment of functional connectivity is based on recent findings of landscape ecology. Nevertheless, the developed aggregation of different concepts and methods forms an innovative operational method adapted to impact assessment studies. The proposed approach allows to include into impact analysis relevant elements, such as habitat spatial relationships defined within multiple scale framework, crucial in biodiversity conservation (Noss 1990; Opdam et al. 2003).
Besides, the methodology may help to answer the common questions of different phases of planning. Within the preliminary analyses, the methodology application may provide

insights about ecological functioning of current landscape structure. Within the design of plan alternatives, the methodology allows depicting the potential impact on habitats and on processes sustaining the local biodiversity. Within scenario evaluation, value-based information can be provided in addition to appraisal of habitat losses.

Tab. 3.8 Contribution to landscape planning: characterization of ecological values and preliminary indications for strategies.

	CONNECTIVITY VALUE			
HABITAT VALUE	High	Medium	Low	Negligible
High	Highly functioning habitat, highly connected ***SOURCE of local biodiversity***		Highly functioning habitats, but isolated or hardly connected ***STEPPING STONE***	
Medium				
Low	scarce habitat functions but well connected ***CORRIDORS***		Areas heavily isolated poorly suitable or negligible for considered communities	
Negligible				

Support to EIA

	CONNECTIVITY VALUE			
HABITAT VALUE	High	Medium	Low	Negligible
High	**Habitat loss,** loss of Breeding sites? Nesting sites? Refuge or feeding sites? **Habitat isolation,** splitting of: "Local" habitat networks? "Regional" habitat network?		**Habitat loss?** Averting opportunities of habitat restoration?	
Medium				
Low	**Habitat isolation?** Impeding future opportunities of network?		No specific indications.	
Negligible				

Support to spatial planning (conservation-restoration)

	CONNECTIVITY VALUE			
HABITAT VALUE	High	Medium	Low	Negligible
High	**PRESERVATION** Preserve from urbanisation or infrastructure development, it may constitute natural reserve		**DE-FRAGMENTATION** Redress the fragmentation (e.g. faunal artificial corridors)	
Medium				
Low	**RESTORATION** Increase habitat functioning, create/restore habitat areas Allow settlement without impacting the connectivity (e.g. orientation of plots)		No specific indications.	
Negligible				

Chapter 4

Study area: Valsugana, an Alpine valley floor

4.1. Introduction

This chapter provides a presentation of the study area and of the general context of the Alpine valley floors. These contexts have significant biodiversity, often disregarded and at the same time are undergoing increasing pressures. In fact, the Alpine region provides a biodiversity reservoir for the whole Europe. The most of biodiversity occurs in human dominated landscapes at lower belts. In Alpine valley floors, while high-specialized agriculture and industrial settlement development are competing for the utilisation of few plane areas, a considerable ecological fragmentation threats the already scattered habitats. In addition, the morphological shape of Alpine valley floors exacerbates the human-driven fragmentation with a "biogeographical" effect, provided by natural barriers as cliffs, steep slopes, and body waters. All these aspects characterize exactly the study area at Valsugana valley, in Trento province.

4.2. Alpine valley floors: biodiversity and competing land uses

The Alps represent a large expanse of natural and semi-natural habitats (Fig. 4.1), which may function as important sources of colonizers for the surrounding intensively cultivated lowlands (Roekaerts 2002). The whole Alpine region is particularly sensitive to ecological variations, to the climate change, to pollution and other human activities. Despite such strategic importance, the Alpine landscapes, then the Alpine valley floors, are currently going through a series of profound changes with unknown biodiversity consequences (Sergio and Pedrini 2007).

Fig. 4.1 The Alps region (source Google maps).

Today in the Alps, around 4500 plant species (Aeschimann et al. 2004) are listed and, among these, 1636 are recorded in Trento Province (Prosser 2001). Among the fauna species, the Italian Alps hold: 200 nesting birds, 200 migrant birds, 21 amphibians, 15 reptiles and 80 mammals (Onori 2004). A complete record of species related to the different Alpine ecosystems is still lacking (Onori 2004).

The most of biodiversity dwells in lower elevation areas. As a matter of fact, the species richness declines with elevation and this elevation gradient produces a biodiversity peak in lower belts (Sergio and Pedrini 2007). Many species, typical of these areas, are today threatened or with decreasing populations (Minelli et al. 1993-1995; in Stoch 2000)

Tab. 4.1 Species relevant for conservation, reported for Adige/Etsch valley floor and nearby valleys (Stoch 2000).

Classification	Species	Conservation status
Arthropoda		
Odonata, Lestidae	Sympecma paedisca	VU
Odonata, Gomphidae	Ophiogomphus cecilia	VU
Coleoptera, Dytiscidae	Graphoderus bilineatus	EN
Coleoptera, Lucanidae	Lucanus cervus	VU
Coleoptera,Cetoniidae	Osmoderma eremita	VU
Coleoptera, Bostrichidae	Stephanopachys substriatus	VU
Coleoptera, Cerambycidae	Cerambyx cerdo	VU
Lepidoptera, Sphingidae	Proserpinus proserpina	DD
Lepidoptera, Sphingidae	Hyles hippophaes	EX
Lepidoptera, Papillionidae	Zerynthia polyxena	LC
Lepidoptera, Lycaenidae	Lycaena helle	EX
Lepidoptera, Lycaenidae	Lycaena dispar	EN
Lepidoptera, Satyridae	Coenonympha oedippus	EN
Lepidoptera, Satyridae	Lasiommata achine	NT
Vertebrata		
Amphibia, Urodela	Triturus carnifex	LC
Amphibia, Anura	Bombina variegata	LC
Amphibia, Anura	Bufo viridis	LC
Amphibia, Anura	Hyla intermedia	LC
Amphibia, Anura	Rana dalmatina	LC
Amphibia, Anura	Rana (Pelophylax) lessonae	LC
Amphibia, Anura	Rana (Pelophylax) ridibunda	LC
Reptilia, Testudines	Emys orbicularis	VU
Reptilia, Squamata	Lacerta bilineata	LC
Reptilia, Squamata	Podarcis muralis	LC
Reptilia, Squamata	Hierophis viridiflavus	LC
Reptilia, Squamata	Natrix tessellata	LC
Mammalia, Rodentia	Muscardinus avellanarius	LC

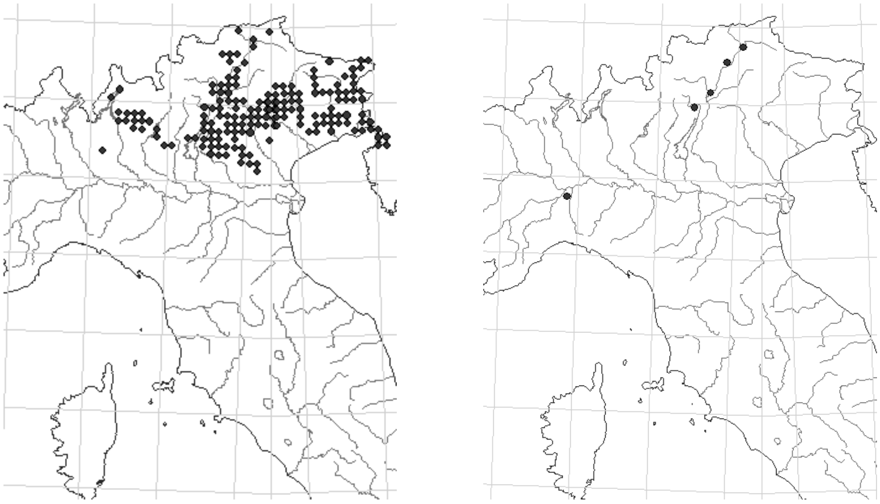


Fig. 4.2 Distribution of *Bombina variegata* and past distribution of *Licaena helle* (Stoch 2000)

In spite of this, in the Alps, the main attention still focuses on the high altitude and more natural areas, with high scenic beauty. Even though in 2003 total amount of natural reserves (under different categories) was 33.000 km^2 (about 18% of the whole Alpine regions included by the Alps Convention), protected areas are often located at high elevation and actually do not represent the whole variability of Alpine ecosystems (Bätzing 2003; Sergio and Pedrini 2007). Otherwise, a large group of species reported in Red Lists dwells in the low elevation areas of valley floors. In some cases, the valley floor provided even the unique habitat area for species, today extinguishing or already extinguished (Fig. 4.2).

Moreover, the Alpine valley floors have a particular morphology that exacerbates the conflict between the different land uses. The Alpine glacial valley is relatively recent and received its final geomorphologic shape as a result of still acting tectonic movement. Because of their steepness and their only occasionally existing terraces, the slopes of the Alpine valley offer usable agricultural or settlement areas only to a limited extent. The Alpine valleys have often morphological bottlenecks (plane area transect < 1-2 km), in which infrastructures predominate entirely the plane area.

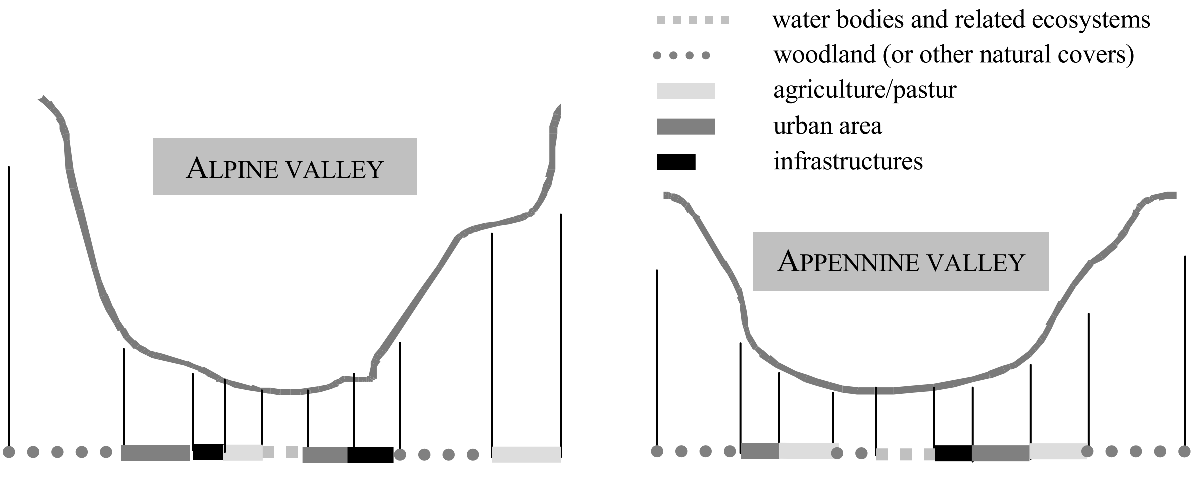


Fig. 4.3 Common profiles of valleys and land use in the Alps and Apennines.

These facts make the Alpine valley floors different from other valley floors, such as those of Apennine. The Apennine valley floor has smoother slopes and usually wider plane areas. This has generally allowed development of scattered settlement and agricultural areas and facilitated maintaining of remnant natural and semi-natural areas.
Today, the main Alpine valley floors have been entirely drained, levelled and improved. Small shaped nature reserves are frequent, but they are quite scattered and generally lacking in continuity. In the place of original river-meadow forests and marshes, previously extended, today intensively farmed fruit and vineyard cultivation characterize these landscapes. The agriculture have modified the Alpine valley floors for centuries, forming cultural landscapes (Lichtenbergen, 1994 in Sergio and Pedrini 2007). A part of biodiversity itself in the Alpine region depends on these cultural landscapes (Laiolo et al. 2004; Preiss et al. 1997). Today, by the intensification of the production, the “agriculture both creates pressures on the environment and plays an important role maintaining many cultural landscapes and semi-natural habitats” (Tappeiner et al. 2003). The agricultural enterprises are extremely small, with average usable agricultural area of 1.8 hectares (Tappeiner et al. 2003). Limited farm size and lack of available areas disable the enlargement of farms and incite an even more intensive farming of the available fields. Consequently, permanent crops may threat the water quality and the surrounding ecosystems. Since fruit farms apply even more than 75 kg of chemicals on each cultivated hectare (Lazzerini 2005), consequent pollution of ponds and drainages can be serious.

4.3. Valsugana valley floor: the study area

The Valsugana valley is part of Trento province and shows conditions similar to many other Alpine valleys. In Trento province, the main valley floors are dominated by various infrastructures; national roads, main and secondary roads and agricultural tracks, drainages ditches, as well as natural gas pipeline, contribute to the splitting of space.
According to the SUSTALP project study (Tappeiner et al. 2003), the Valsugana valley has characteristics of region type 1 and type 4. Region type 1 is “a labour-intensive crop region in favourable location with small-scale farm structure”. This kind of region is mainly characterized by high percentage of permanents crops. Predominately the Region type 1 can be found along the Adige/Etsch valley at the southern border of the French Alps. Region type 4 is characterized by “small scale grassland farms in favourable locations with a surplus of labourers”. It could be found exclusively at the southern-eastern border of the Italian Alpine arch. In region type 4 grassland farming and arable cropping, especially maize, characterizes the agricultural production. While, in the last few years, the horticulture, i.e. berries cultivation, have been becoming an attractive opportunity (Tappeiner et al. 2003).

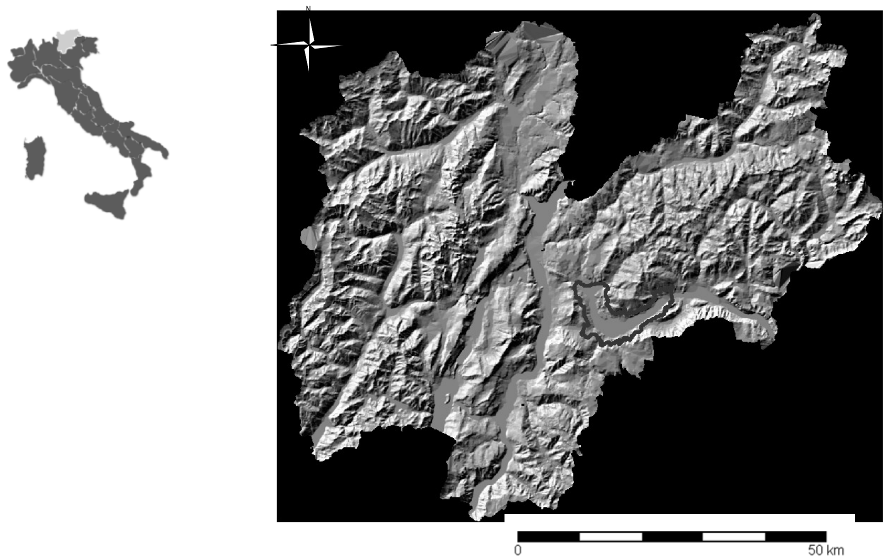


Fig. 4.4 Study area and Trento province (northern Italy).

As in other valleys floors, villages are found primarily on the gentler slopes, as well as on conoids, which were deposited by tributary streams that flow into the main valley. More than 80% of provincial population inhabits areas below 750 m of altitude (Zanon 2005). Recently, good infrastructure connections with the nearby conurbations, as Trento (for Adige valley) or Pergine (for Valsugana valley), have induced the development of industrial settlement, shopping centres and other larger concerns. These settlements cause a further considerable splitting effect of the space, in addition to the networks of routes oriented along the valley floor.

In some areas, the settlement structure has already an urban character, with residential areas and dormitory towns. This process can be recognized by trend of population density in the last decades. In particular, it is possible to identify two kinds of trend for the main municipalities located along the Valsugana valley floor. An increasing one is likely due to the proximity of the urban area of Trento (Pergine), typical of region type 1; another quite stable or slowly growing is typical of region type 4 (Fig. 4.5).

A further indicator of urban character developing is the ratio between the urbanized areas and inhabitants. This ratio increased in Valsugana valley from 380.9 m^2/inhabitant in 1990 to 422.9 m^2/inhabitant in 2000 (+ 11%), while in Adige valley from 271.8 m^2/inhabitant in 1990 to 297.4 m^2/inhabitant in 2000 (+ 9%) (Zanon 2005).

In addition to the spreading of urban areas, an increasing pressure on valley floor environments comes from the human activities as tourism. This has been driving the "second house phenomenon" in Switzerland, France and Italy (except Southern Tirol, Hain 2004). For Italy, Bätzing (2003) stated that "while in France and Switzerland these settlement developed in well planned manner, in Italy this development was wild". Besides the settlement, the growing number of tourists and spreading sport activities in the territory (e.g. biking, hiking, canyoning) may entail further increasing disturbances on habitats.

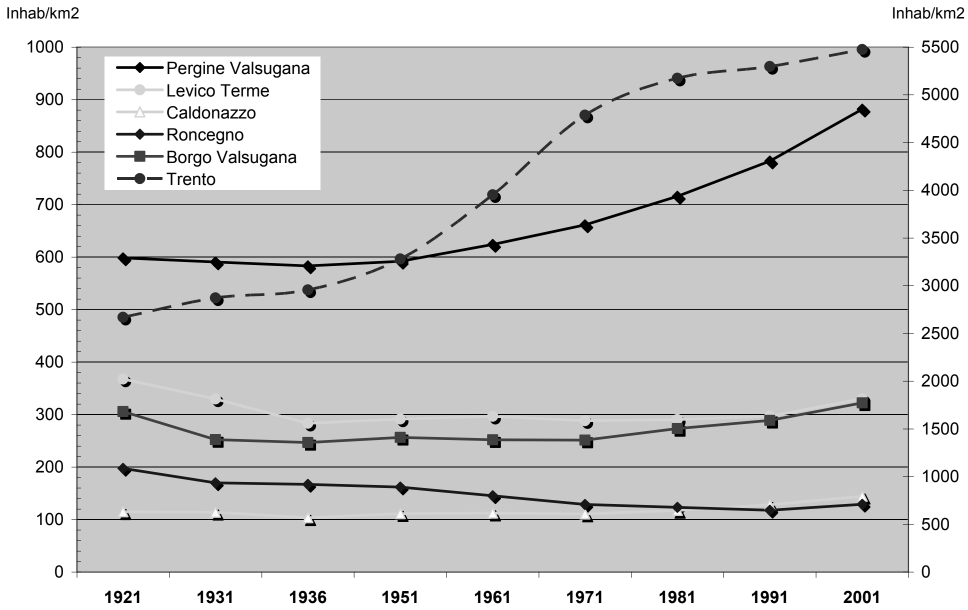
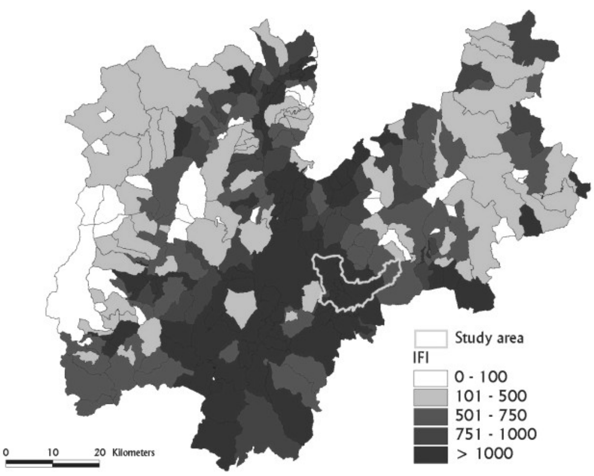


Fig. 4.5 Population density dynamics in some of the municipalities of Valsugana valley, Pergine is the closest village to town of Trento (the two higher trend lines refer to the right vertical axis).

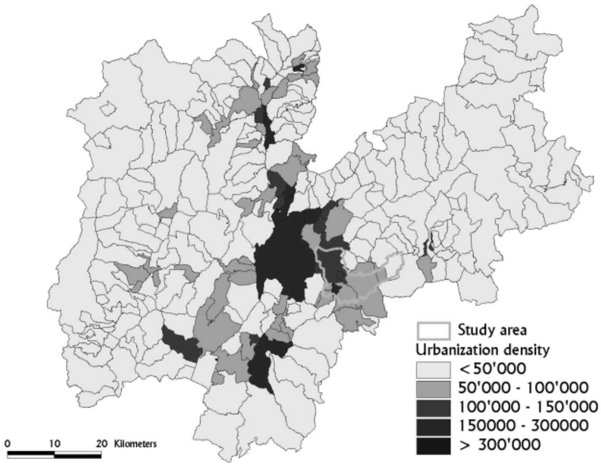
The increasing pressures on valley floors are also highlighted by the Infrastructure Fragmentation Index and the Density of Urbanization index (Romano and Paolinelli 2007). The two indices indicate pressures on different components of biodiversity. In fact, the structural fragmentation (due to infrastructures) may affect heavily the terrestrial fauna, hampering dispersal of mammals, amphibians or reptiles. Conversely, the urbanization density may impact the avifauna species, being particularly sensitive to this variable (La Rovere et al. 2006). The maps of these indices make self-evident the main valley floors, with higher values.



$$IFI = \frac{\sum l_i * O}{A_u} \quad (m/km)$$

l : length of each line of roads network
o : weights for roads classes
A_u : area of landscape unit of analysis (municipality area)

Fig. 4.6 Infrastructural Fragmentation Index for Trento province, in terms of m^2/km^2.



$$DU = \frac{\sum Aurb_i}{A_u} \quad (m/km)$$

Aurb : urban area
A_u : area of landscape unit of analysis (municipality area)

Fig. 4.7 Urbanization Density Index for Trento province, in terms of m^2/km^2.

4.3.1. Boundaries of the study area

Since the study is meant to analyze landscape ecological functions it required the study area be identified by ecological bases. Aerial photographs and digital terrain model provided clear indications for identification of the study area boundaries.

The southern and northern boundaries appear clearly visible, being defined by typical morphology of Alpine valley floor, with orientation approximately west-east. The valley slopes consist in steep hills on north and south-west sides and rock cliffs on south-east sides.

The eastern and western boundaries of the study area are less self-evident; anyhow they have a reliable ecological basis. In fact, the study area extents from the fluvial area of Fersina stream (west) to the valley bottleneck in the municipality of Roncegno. At the west side of study area, the Fersina fluvial area is highly artificial and delimited by concrete banks; furthermore, industrial sites enclose almost completely the area. At the opposite east side, very steep hillsides shape a valley bottleneck in which the narrow plane area is dominated by urban areas and infrastructures. Thus, also at the west and east borders of study area it is possible to assume an environmental discontinuity, due to morphologic and human-driven causes.

Concerning the definition of valley floor, the elevation of 800 m was considered as threshold. This threshold means a change of vegetation cover but, above all, of animal populations, especially for the small species. In effect, the steep elevation gradient may likely constitute a barrier to meso-fauna species dispersal.

Within these boundaries, the study area covers about 100 km^2. This area is large enough to likely hold local populations of small species. Considering these facts, only few exchanges of individuals may be assumed occurring between habitats outside the study area. Thus, habitat loss and fragmentation within the so defined area might really increase the extinction probability for local populations.

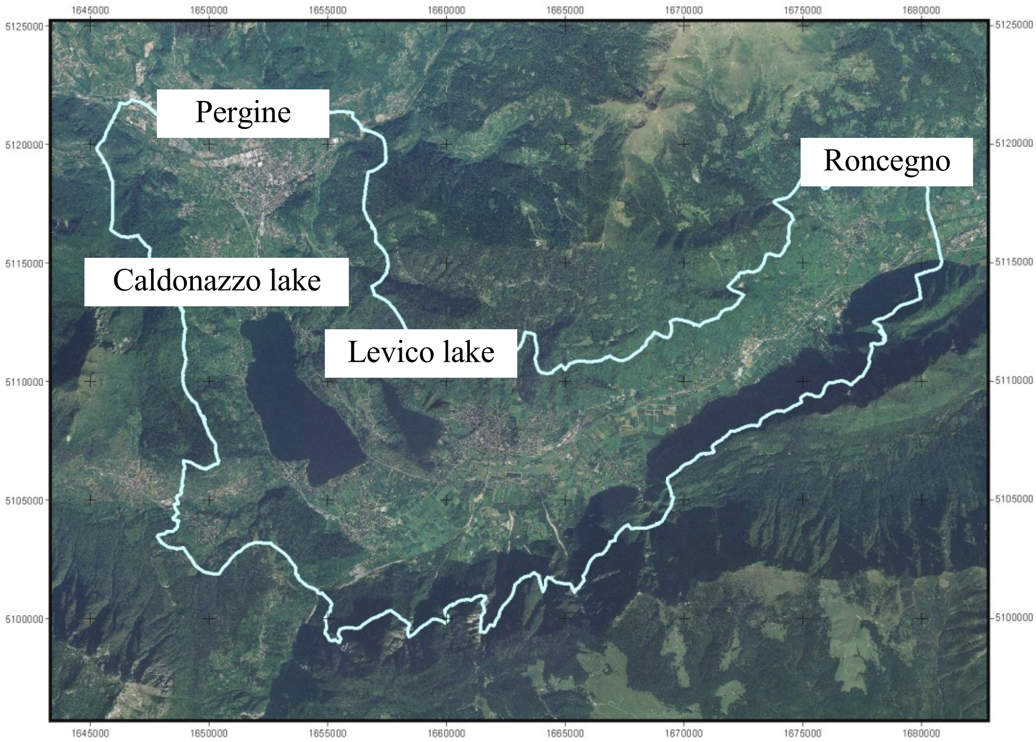


Fig. 4.8 Aerial photo of study area: the upper section of Valsugana valley floor.

4.3.2. Biodiversity assets

Besides wooded slopes, Valsugana valley floor presents remnant natural areas and natural reserves. In particular, the study area includes nine Special Areas of Conservation (SAC), named by provincial legislation as protected areas ("biotopi provinciali"), six local nature reserves, named "biotopi comunali" but actually not protected by the law. All these areas are related to the wetland and water bodies of the valley floor, such as Caldonazzo Lake, Levico Lake, the Brenta river and several ditches or secondary streams.

Code	Name	Hectares	Number of animal species recorded
IT3120091	ALBERE' DI TENNA	6.822	18
IT3120123	ASSIZZI - VIGNOLA	87.569	9
IT3120042	CANNETI DI SAN CRISTOFORO	9.393	52
IT3120039	CANNETO DI LEVICO	9.743	50
IT3120038	INGHIAIE	30.104	82
IT3120041	LAGO COSTA	3.826	63
IT3120033	PALUDE DI RONCEGNO	20.599	51
IT3120043	PIZE'	15.912	48
IT3120125	ZACCON	371.199	15

Tab. 4.2. Special Areas of Conservation included in study area.

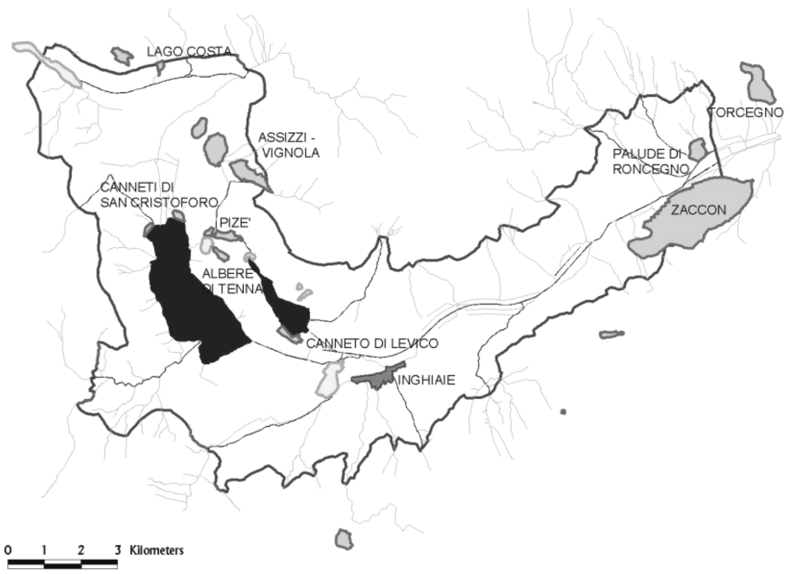


Fig. 4.9 Local nature reserves (dark yellow= SAC areas, light green=local reserves).

These environments provide suitable habitat for numerous species, namely: 82 bird species, 17 mammal species, 62 insects species, 9 reptile species and 6 amphibian species are reported (Servizio Parchi e Conservazione della Natura 2003). In particular, these areas hold 9 species listed in Annex II of 92/43/CEE "Habitat" and 18 species in Annex I of Directive 79/409/CEE "Birds". Concerning the vegetation, a total of 452 plant species live in valley floor of Valsugana. Besides, in this zone, four areas are identified as "vulnerable floristic area" because of the occurrence of endangered species and Alpine endemisms (Prosser 2001).

BIRDS	FISHES
Alcedo attui	*Barbus plebejus*
Ardea purpurea	*Chondrostoma soetta*
Botaurus stellaris	*Cobitis taenia*
Ciconia ciconia	*Cottus gobio*
Circus aeruginosus	*Lethenteron zanandreai*
Crex crex	
Dryocopus martius	INSECTS
Ficedula albicollis	*Lucanus cervus*
Ixobrychus minutus	*Lycaena dispar*
Lanius collurio	
Luscinia svecica	AMPHIBIANS
Milvus migrans	*Bombina variegate*
Nycticorax nycticorax	*Bufo bufo*
Pandion haliaetus	*Rana dalmatina*
Pernis apivorus	*Rana esculenta*
Philomachus pugnax	*Salamandra salamandra*
Picus canus	*Triturus alpestris*
Porzana porzana	MAMMALS

Tab. 4.3 Species present surveyed in SACs, listed in "Habitat" Directive and "Bird" Directive.

These environments constitute a biodiversity reservoir and a source of ecosystem services. At the same time, these areas are undergoing to land-use changes, with unknown consequences on this bioversity. Keeping their integrity would requires also preserving traditional human activities, such as forage, mowing or tree cutting (Prosser 2001). Both land abandonment and intensification of agricultural activities may threat these small ecosystems. Again, their ecological functioning is dependent on linkages to each other and connectivity with other natural and semi-natural areas. Thus, the preservation of these areas is conflicting with actual human activities evolvement, such as specialized intensive cultivation and industrial/urban development. Somehow, this is a common situation in all Alp regions.

4.3.3. Land-use and fragmentation

The study area is mainly covered by agriculture areas or by natural and semi-natural vegetation (Fig. 4.10), meaning broad-leaved forest, coniferous forest, mixed forest, transitional woodland-scrub, natural grasslands, moors and heath land, water bodies. These kind of covers allow animal movement, in other words they provide a "bio-permeability" (Romano 2002). The bio-permeability apparently depicts the study area as continuous or scarcely fragmented.

On the other hand, scattered settlements, isolated small urban areas may cause a "perforation effect", by inducing or facilitating subsequent phases of fragmentation (Forman 1995; Jaeger 2000b). In addition, larger developing urban areas may cause an "attrition effect", sealing soil and removing habitats. Considering the areas actually affected by these fragmenting elements, i.e. considering different distances of influence (using buffer operation), it is possible to make evident the actual fragmentation of study area. This shows more realistically split and reduced natural and semi-natural areas.

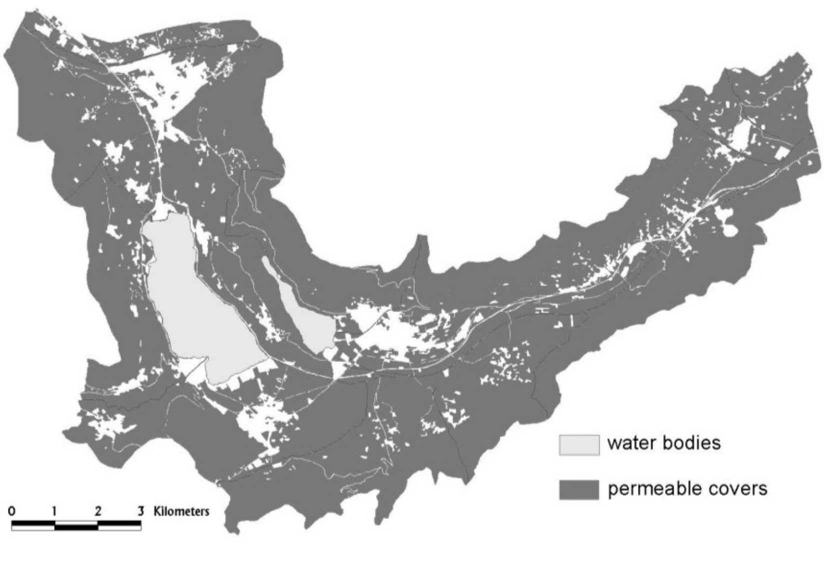


Fig. 4.10 Bio-permeable covers within study area.

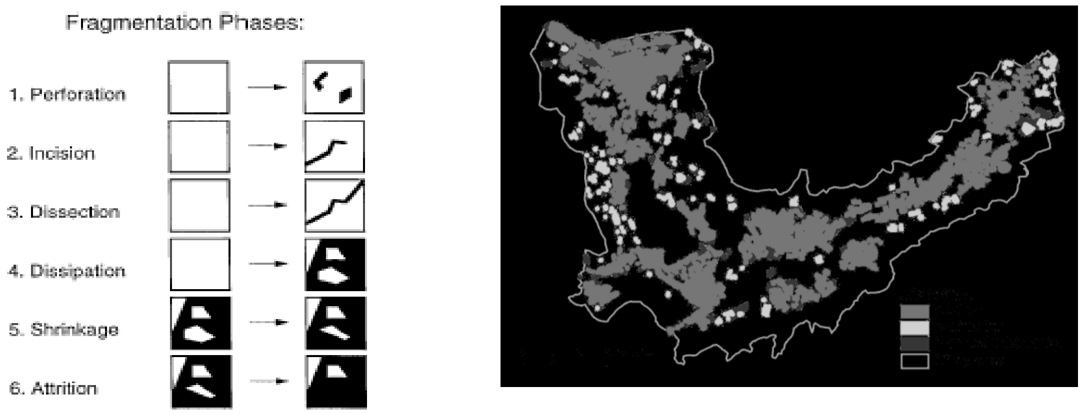


Fig. 4.11 Fragmentation phase sequence (source Jaeger 2000b), fragmenting features related to different phases

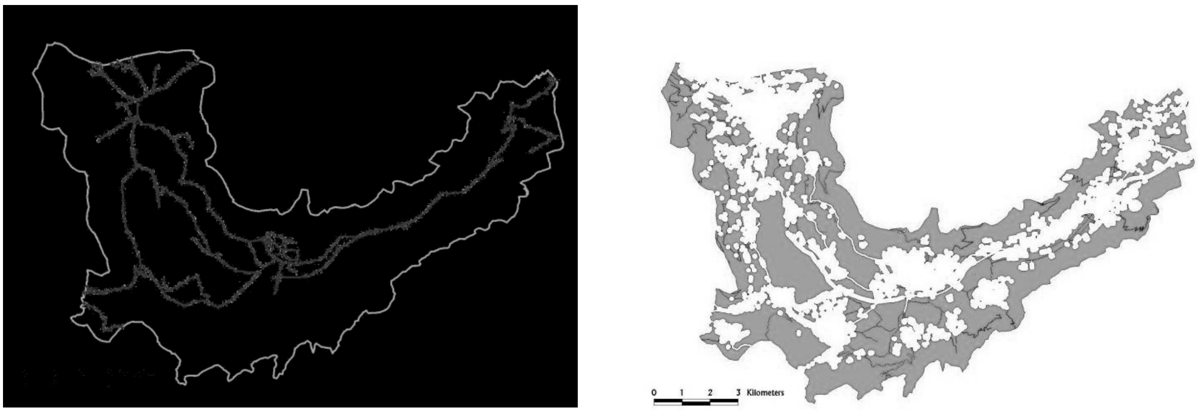


Fig. 4.12 Road network and the remnant natural or semi-natural areas resulted by removing the area directly affected by the roads and urban areas.

Any further land-use changes in the study area, generally as well as in other Alpine valley floors, may very likely threat local biodiversity, affecting the vulnerable processes sustaining it. In order to minimize impact on biodiversity there is need of understanding the ecological spatial relations between natural areas, and evaluating their actual functioning. This understanding may guide spatial planning towards preventing habitat loss in future, or at least towards compensating the unavoidable impacts. The application of proposed methodology was meant to contribute exactly to this understanding, as shown in the next chapter.

Chapter 5

Application of the methodology in the study area

5.1. Introduction

This chapter presents the application of the proposed approach, following the procedure steps shown in chapter 4. The methodology is applied to the study area, described in the previous chapter, with the aim of testing its usefulness and identifying its limits. The application outputs provided basic information about ecological processes sensitive to land cover changes, and about their actual functioning. These established a ground for operational indications provided in a real case of spatial planning, presented in the next chapter. In the last paragraph, innovative aspects and limits of the present methodology are briefly discussed.

5.2. Land cover and ecosystems

The assessment methodology relies on vegetation cover data and land cover map. The first is mainly used for habitat classification, according the habitat requirements of target species. The second is used principally in the assessment of functional connectivity, based on species-specific barrier effect. Thus the legend of the basic map had to provide suitable thematic resolution to distinguish habitat functions (supported by different vegetation structure and composition); the spatial resolution had to allow recognizing any landscape element providing a barrier to species dispersal.
A detailed (1: 10,000) land-use map (up-dated in 2000) was available, when this study was undertaken. This map is based on the legend produced in the framework of the EU project "CORINE-Land Cover" (European Commission 1993). This provides information focused on land-use, differently concerning vegetation covers broad classes are set (e.g. only three woodland types are distinguished). Besides, it obviously does not consider the barrier characterization. For these reasons, an original land cover map was produced, by updating and improving the existent land-use map. In particular, the land cover mapping was carried out from the following available data:

- Ortho-corrected aerial photos, acquired in 2000, with a spatial resolution of 1 m
- Ortho-corrected aerial photos, acquired in 2006, with a spatial resolution of 0.5 m
- Forest inventory map, based on forest parcels, updated at 2003
- Land-use map, updated at 2000, cited above.

In practice, the land cover mapping was developed in two steps. The first consisted in digitalizing the vegetation and land cover by updating the 2000 land-use map to 2006 (using the aerial photos). The covers were subsequently adjusted according to a ground-truth, depicted by field surveys. The field surveys were conducted in summer and autumn 2007 and in spring 2008.

The land cover classification was defined according to the European standard for habitat classification: European Nature Information System, EUNIS (European Environment Agency 2007). This standard, revised in 2004 (Davies et al. 2004), is developed and managed by the European Topic Centre for Nature Protection and Biodiversity (ETC/NPB in Paris) for the European Environment Agency (EEA) and the European Environmental Information Observation Network (EIONET).

The EUNIS habitat system consists of a database together with explanatory documentation. EUNIS habitats are arranged in a hierarchy system, starting at the level 1 (with 10 categories), in which marine habitats are listed down to the level 4 and terrestrial and freshwater habitats to the level 3. Most EUNIS habitats are in effect ‘biotopes’, that is to say ‘areas with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms’ (EEA, 2008). Precisely, the EUNIS habitats of the level 1 are:

A. Marine habitats
B. Coastal habitats
C. Inland surface waters
D. Mires, bogs and fens
E. Grasslands and lands dominated by forbs, mosses or lichens
F. Heathland, scrub and tundra
G. Woodland, forest and other wooded land
H. Inland unvegetated and sparsely vegetated habitats
I. Constructed, industrial and other artificial habitats

The level 2 and the level 3 are named by an alphanumerical code, for example “G1” means the “broadleaved deciduous woodland” and “G1.1” means “Riparian and gallery woodland, with dominant Alnus, Betula, Populus or Salix”, as shown in Annex I. All but the smallest EUNIS habitats occupy at least 100 m^2 (in some special cases are only a few m^2); there is no upper limit to the largest.

In the framework of the present study, the thematic resolution was based on the third level of EUNIS 2004 hierarchy, defining approximately 50 m^2 as the minimum area. During the digitalization on aerial photos, smallest linear landscape objects (as hedgerows or tree line) were at least 2 m of thickness and 20 m of length.

During the field surveys, the classification manual edited by Davies et al. (2004) was used instead of the Italian version, published in the same year by national environmental agency

APAT (Lapresa et al. 2004). This was because the Italian version appeared referring to the EUNIS version 2001 and not completely coherent with EUNIS 2004. Thus, the classification of covers was performed following the keys (provided by the manual) from the first to third of EUNIS levels, referring to the listed phytosociological units in undecided cases of level 3 classes.

Not all of the EUNIS classes were found in the study area. Finally, 8 classes of level 1, 26 classes of level 2 and 74 classes of level 3 were identified. The results of land-cover classification are shown in Fig. 5.1 and in Tab. 5.1 .

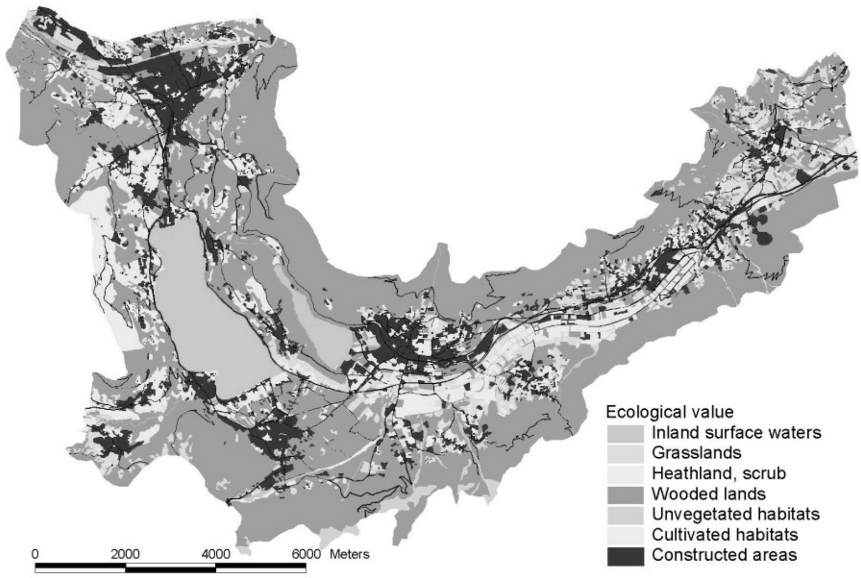


Fig. 5.1 Level 1 Habitats for Valsugana study area.

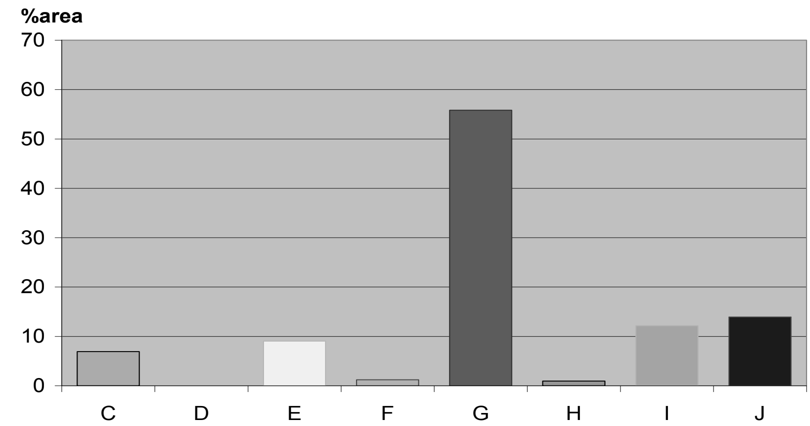


Fig. 5.2 The EUNIS classification for study area.

The study area is covered mainly by wooded land. The level 1 class “G” covers more than 50% of study area Fig. 5.2. More in detail, the “broadleaved deciduous woodland” (“G1”) and the “mixed broadleaved and coniferous woodland” (“G4”) are the most common in level 2 class, as shown in Tab.1. It should be noted that this class includes also non-natural wooded areas as “Fruit and nut tree orchards” (G1.D). This vegetation is composed mainly of apple orchards, which covers nearly 9% of study area .

Among deciduous woodlands the “Thermophilous deciduous woodland” type (G1.7) is the most diffuse, covering 18% of study area. This woodland is typical for sub-Mediterranean climate regions and supra-Mediterranean altitudinal levels, dominated by deciduous or semideciduous thermophilous *Quercus* species or by other southern climate trees such as *Castanea sativa, Fraxinus ornus,* and *Ostrya carpinifolia*. This class includes numerous phytosociological units related to each other, namely: *Alnion incanae; Fraxino orni-Cotinion; Tilio-Acerion; Salicion albae; Genisto germanicae-Quercion*. The other important woodland class is “mixed broadleaved and coniferous woodlands” (G4.8), composed of *Pinus orPicea* (in semi-natural forestry plantations) and *Fagus* species.

Tab. 5.1 Level 2 Habitats cover statistics.

Level 2 Habitats		Sum (ha)	Aver. (ha)	Count	Max (ha)	Min (ha)
Surface standing waters	C1	635,60	70,62	9	358,02	0,12
Surface running waters	C2	39,81	0,56	71	3,15	0,01
Littoral zone of inland surface waters	C3	58,70	0,62	94	5,24	0,01
Valley mires, poor fens and transition mires	D2	0,95	0,47	2	0,61	0,34
Mesic grassland	E2	828,14	1,41	588	13,88	0,01
Seasonaly wet and wet grassland	E3	16,13	0,70	23	2,95	0,02
Woodland fringes and () tall forbs stands	E5	104,04	0,63	166	32,39	0,01
Sparsely wooded grasslands	E7	2,57	0,51	5	0,95	0,03
Temperate and Mediterranean () scrub	F3	0,82	0,82	1	0,82	0,82
Riverine and fen scrubs	F9	32,17	0,56	57	8,75	0,02
Hedgerows	FA	9,87	0,16	62	0,78	0,01
Shrub plantations	FB	85,08	0,98	87	9,69	0,01
Broadleaved deciduous woodland	G1	3047,47	5,58	546	169,00	0,01
Coniferous woodland	G3	414,77	11,52	36	108,02	0,13
Mixed broadleaved and coniferous woodland	G4	2129,23	15,21	140	108,44	0,01
Small anthropogenic woodlands ()	G5	313,49	0,64	493	11,75	0,01
Screes	H2	27,44	1,44	19	5,63	0,05
Inland cliffs	H3	73,39	3,34	22	20,93	0,01
Arable land and market gardens	I1	1198,66	1,83	656	38,69	0,01
Cultivated areas of gardens and parks	I2	84,66	1,39	61	11,15	0,05
Buildings of cities, towns and villages	J1	444,01	4,48	99	40,91	0,01
Low density buildings	J2	669,12	0,53	1260	15,96	0,01
Extractive industrial sites	J3	47,11	2,48	19	17,05	0,04
Transport networks ()	J4	301,80	0,65	466	6,96	<0,01
Highly artificial man-made waters	J5	2,50	0,31	8	1,13	0,03
Waste deposits	J6	9,56	0,74	13	2,94	0,11

The presence of non-native species have created some difficulties in woodland classification. In many cases the exotic species *Robinia pseudoacacia* (rarely also *Ailanthus altissima* sp.) have colonized and now dominates remnant oak or riparian woodlands, making difficult to recognize the original composition and the actual habitat functioning. The forest inventory

map (updated in 2003) did not help much, because the classification focused more on forestry productivity of coniferous than distinguishing deciduous woods.
The agriculture areas, including “Fruit and nut tree orchards”, are 12% of study area. The arable lands are almost totally dedicated to corn production. The grasslands are mainly “low and medium altitude hay meadows” (“E2.2”), in some cases “heavily fertilized” (“E2.6”). The artificial covers represent about 14% of study area, mainly consist in “low density buildings” (J2) and “transport networks” (J4), i.e. “scattered residential buildings” (J2.1) and “road networks” (J4.1). Some covers, in spite of representing lesser part of study area, are really important regarding the local biodiversity (as shown in the next paragraphs), such as: “Hedgerows”, “Littoral zone of inland surface waters”, “Poor fens and transition mires”, “Riverine and fen scrubs” and “Seasonally wet and wet grasslands”. Only through a detailed land cover mapping it was possible to define and appreciate them.

5.3. Definition of Patches, Units, and barrier characterization

In the framework of this study I defined a Patch as a vegetated area or body water identified by a polygon (in a land cover vector map) classified by third level of EUNIS standard. Concerning the Units, practically two types of Unit were identified aiming at fitting the definition for terrestrial species and for amphibians. Thus, the Unit definition was performed through two methods: for terrestrial species water bodies and “littoral zones” such as lakes, streams, springs, ditches were considered as barriers, i.e. Unit borders, on contrary for amphibians all these elements were included within Units. Operationally, all the Patches providing a possible habitat were merged in larger polygons (in another layer). The resulted areas, excluding the smaller than 1 ha, were identified by a ID-Unit value. This ID was subsequently assigned to original Patches belonging to a certain Unit. This allowed performing landscape analyses and evaluation at two scales based on the same layer, using different ID fields.
Concerning the barriers to animal dispersal, during the field surveys possible natural and artificial barriers were annotated and characterized. Natural barriers are represented by rivers, streams, lakes, pools and ditches, i.e. the land covers listed as “C” of the level 1 classes. According to the depth of the water and distance between the banks, various landscapes elements defined as barriers were classified in previously established categories (see the § 4.4.2). In particular, the two lake of Caldonazzo and Levico are considered as total barriers. Artificial barriers are represented by constructed areas, i.e. all features belonging to “J” and “I.2” (gardens) classes. Walls, fences, enclosures of land covers were also considered. These elements were reported in additional attribute field of the GIS-layer (see Annex. In the case of water bodies or road segments enclosed by artificial banks or walls this information was annotated as an additional barrier (in another table-field). I excluded from

this classification walls and banks that are not vertical and made with natural materials (as those constructed by soil bioengineering projects).

5.4. Habitat potential

5.4.1. Target species and ecological profiles

The selection of target species followed the criteria mentioned in § 4.3.1. According to these criteria, the target species should represent a wide range of dispersal distance, home range and sensitivity to fragmentation and land cover change. The selection originated in a draft list of species, chosen among those surveyed within the 40 provincial biotopes located at valley floor. The candidates species were characterized by area requirement and dispersal distance, as in Tab. 5.2.

Tab. 5.2 Draft list of candidate species (in brackets the total number of species for the group).

	Amphibian (12 species)	Birds (199 species)	Mammals (27 species)	Insects (175 genus)
Wetland	Bombina variegata[a, e, h, g] Rana synk. esculenta[a, e, h, g] Rana dalmatina[a, e, h, g]	Ixobrychus minutus[b, f] Acrocephalus palustris[b, f]	Neomys anomalus Crocidura suaveolens	Sympetrum spp.[c, l] Calopteryx virgo[c, d, l]
Woodland		Picus viridis[f] Sitta europaea	Meles meles Eliomys quercinus Muscardinus avell.[a, e, m]	Cerambyx cerdo[a, d] Lucanus cervus[a, d]
Grassland		Lanius collurio[b, f] Motacilla flava[f]	Erinaceus europaeus[e] Talpa europaea Lepus europaeus	Lycaena dispar[a] Maculinea arion[a]

a: included by Habitat Directive; b: included by Birds Directive; c: Swiss Dragon Fly Red List (Gonseth and Monnerat 2002); d: Insect Red List (Friuli V-G Region); e: Protected species in Bolzen province (L.P. nr. 27/1973) and in Britain f: Birds Red List for Trento province (Pedrini et al. 2005); g: Amphibian Red List for Trento province (Caldonazzi et al. 2002); h: Swiss Amphibian Red List (Schmidt and Zumbach 2005); l: Red List for Bolzen province (Provincia autonoma di Bolzano/Alto Adige 1994); Italian Vertebrates Red List (Bulgarini et al. 1998).

Tab. 5.3 Characterization of species in terms of dispersal and home range (modified from Sluis et al., 2003).

	Short dispersal distance 0,1 - 1 km	Middle dispersal distance 1 – 3 km	Large dispersal distance 3 - 10 km
Small individual area requirements $< 0,1$ km^2	Bombina v., Lycaena d., Lucanus c., Rana synk. esculenta	Sympetrum ssp., Calopteryx virgo, Cerambyx c.	
Middle individual area requirements 0,1 - 1 km^2	Muscardinus avellanarius	Erinaceus e.	
Large individual area requirements 1 - 10 km^2		Lanius collurio (in breeding period)	Lepus europaeus Meles meles, Sitta europaea

Eventually, two species for each habitat type were selected: Hazel Dormouse (*Muscardinus avellanarius*) and Nuthatch (*Sitta europaea*) for woodland, Hedgehog (*Erinacaeus europaeus*) and Red-backed Shrike (*Lanius collurio*) for grassland, Ediblefrog (*Rana synklepton esculenta*) and Damselfly (*Calopteryx virgo*) for wetland.
By a specific literature review, information on species ecology was gathered composing the relative "ecological profile" (shown in Tab. 5.4). Over and above reviewing specific literature, I consulted fauna experts (researchers and professors) belonging to different research institutes (e.g. Bogliani, Boitani, Massa, Padoa-Schioppa, Pedrini, Santolini and Pouwels). The ecological profiles grounded the development of the conditional rules for habitat potentialclassification, as mentioned in the chapter 4. These rule sets are shown in Tab. 5.6, Tab. 5.7,

Tab. 5.8,

Tab. 5.9,

Tab. 5.10 and Tab. 5.11.

Tab. 5.4 Ecological profiles of the focal species for study area.

	Density (RU/ha)	Min. Key Patch Area (ha)	Min. Key population (RU)	Stepping stone minimun area (ha)	RU for Stepping stone	Home range (m)
Ediblefrog	100 – 1000 [a]	5	500 [a]	1	100	300 [b]
Damselfly	100 – 1000	5 [c]	500 [c]	0,5 [c]	50 [c]	500 [c]
Hedgehog	0.3 – 0.7 [d, e]	40 [f] - 50 [d]	40 [a] -100 [d]	5 [d]	10 [d]	1500 [g]
Red-backed shrike	0.3 [h, i]	120 [l]	40 [l, m]	10	4 [b]	500 [n]
Hazel Dormouse	5 [o]	20 [p, q]	100 [l]	5	25	100 [p, q]
Nuthatch	0.2 - 1 [a, r]	40 [l, r]	40 [l]	5 [s, t]	4	1500 [u, v, z]

a: (Vos et al. 2001); b: (max distance recorded 1.2 - 15 km in review of Smith and Green 2005) and (empirical study: daily dist. 77-328 m in Holenweg Peter 2001); c: Pouwels, 2008 (personal communication); d: (van Rooij et al. 2003); e: (Huijser and Bergers 2000); f: (Young et al. 2006); g: (average home range 0.8 km, most frequent dist. 2-4 km, max <10 km in Doncaster et al. 2001) and (average linear trajectory 380 m, by radio-location, within 5 ha in Rondinini and Doncaster 2002); h: Massa, 2007 and Pedrini, 2007 (personal communication: common density in Trento province 1 ru/3-4 ha of rural suitable area); i: (measured density: 3.2-5.1/10 ha in Brambilla et al. 2007); l: (Verboom et al. 2001a); m: (Takács. et al. 2004); n: (dist. between territories in Vanhinsbergh and Evans 2002); o: (Berg and Berg 1998); p: (Bright and Morris 1995); q: (Bright et al. 1994) and (Bright 1998); r: (Bellamy et al. 1998) and (Telleria & T. Santos 1993) and (González-Varo et al. 2008); s:(van Langevelde 2000a); t: (Hanski 1994); u: (half of meaningful isolation measure of 3 km in Matthysen 1999); v: (Matthysen et al., 1995); z: (Matthysen and Schmidt 1987).

Concerning the calculation of Unit Habitat Potential (UHP), in the defined formula [1] (see § 4.3.3) the species density were set as in Tab. 5.5.

$$[1]\ Ucc_{j-species}(i) = \sum_{l \in S(Unit_i)} a_l \times d(S,j) + \sum_{h \in B(Unit_i)} a_h \times d(B,j)$$

Tab. 5.5 Density values used for Unit Habitat potential calculation.

	Edible frog	Damselfly	Hedgehog	R.-b. Shrike	Dormouse	Nuthatch
Breeding (RU/ha)	100	100	0.3	0.3	5	0.8
Survival (RU/ha)	30	30	0.2	0.1	1	0.2

Tab. 5.6 Classification rule set for *Rana esculenta* based on EUNIS classes (when second or first level class is shown all the lower level classes are included).

Edible Frog	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area >1 ha AND: (Permanent mesotrophic/eutrophic lakes, ponds and pools (C1.2/3) AND <150 m off shore) OR Springs, brooks (C2.1) OR Permanent non-tidal, smooth-flowing watercourses (C2.3) OR Temporary running waters (C2.5) OR Species-rich helophyte bed (C3.1) OR Water-fringing reedbeds and tall helophytes other than canes (C3.2) OR Water-fringing beds of tall canes (C3.3) OR Periodically inundated shores with pioneer and ephemeral vegetation (C3.5) OR Transition mires and quaking bogs (D2.3) OR Seasonally wet and wet grasslands (E3.1/3/4/5, E5.4) OR Riverine and fen scrubs (F9.1)	≥ 100 (100-1000)	At least one breeding area > 3 ha OR breeding and survival patches mosaic within the distance of 300 m AND total area > 5 ha	≥ 500
Survival	Covers AS ABOVE but area <1 e > 0.1 ha OTHERWISE area > 0.5 ha AND Permanent non-tidal, turbulent watercourses* (C2.2) OR *Salix* carr and fen scrub (F9.2) OR Riparian and floodplain gallery woodland, with *Alnus, Betula, Populus* or *Salix* (G1.1/2/3) (* only if with water-fringing vegetation otherwise set Dispersal)	≥ 10	breeding or survival patches mosaic within the distance of 300 m AND total area > 1 ha (including the case of one Breeding/Survival Patch >1 ha)	≥ 100
Dispersal	Covers for Breeding habitat class but area <0.1 ha OR Covers for Survival habitat class but area <0.5 ha OTHERWISE Unvegetated or sparsely vegetated shores with soft or mobile sediments (C3.6) OR Unvegetated OR sparsely vegetated shores with non-mobile substrates (C3.7) Semi-open grassland (mesic, dry) (E1, E2) OR Woodland fringes and clearings and tall forb stands (E5.1/2) OR Sparsely wooded grasslands with trees/bushes (30-50%) (E7.2, F3.1) OR Gardens and allotments with trees/bushes, hedgerows (FA.3/4 OR Shrub plantations (FB.4) OR Deciduous forest (G1.6/7/B/D, G5.1/2/4/5/6/7/8) OR Mixed coniferous and deciduous forest (G4.6/8/C/F) OR Early-stage natural and semi-natural woodlands (G5.6) OR mature coniferus forest (G3.1/4/7/F) OR Mixed crops of market gardens and horticultures (I1.2) OR intensive unmixed cultivated land (arable land, allotment without trees/bushes) (I1.1/3/5) OR Ornamental and domestic garden areas (I2.1/2)	Likely some individuals	Breeding/survival/dispersal cover > 60% of the Unit	Likely some RU
Unsuitable	Sparsely developed land without trees/bushes OR Recently felled areas (G5.8) OR Bedrock (with scattered pine, semi-open, open), unvegetated OR sparsely vegetated habitats (H2/3) OR open water > 150 m off shoreline OR Agricultural constructions (structures connected with agriculture OR horticulture (including greenhouses) (J2.2) OR Highly artificial nonsaline running waters (J5.4)			
Hostile	Developed land with no OR sparse vegetation (0-30%) OR constructed, industrial and other artificial habitats (J)			

Tab. 5.7 Classification rule set for Damselfly *Calopteryx virgo*

Damselfly	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area >0.5 ha AND (Permanent mesotrophic/eutrophic lakes, ponds and pools (C1.2/3) AND <150m off shoreline) OR Springs, brooks (C2.1) OR Permanent non-tidal, smooth-flowing watercourses (C2.3) OR Temporary running waters (C2.5) OR Species-rich helophyte bed (C3.1) OR Water-fringing reedbeds and tall helophytes other than canes (C3.2) OR Water-fringing beds of tall canes (C3.3) OR Species-poor beds of low-growing water fringing OR amphibious vegetation (C3.4) OR Periodically inundated shores with pioneer and ephemeral vegetation (C3.5) OR Transition mires and quaking bogs (D2.3) OR Seasonally wet and wet grasslands (E3.1/3/4/5, E5.4) OR Riverine and fen scrubs (F9.1/2)	≥ 100	At least one breeding patch > 3 ha OR breeding and survival patches mosaic within the distance of 500 m, with total area > 5 ha	≥ 300
Survival	Covers AS ABOVE BUT area >0.05 ha AND area <0.5 ha OTHERWISE area ≥ 0.5 ha AND Permanent non-tidal, fast, turbulent watercourses* (C2.2) OR Unvegetated or sparsely vegetated shores (C3.6) OR Unvegetated or sparsely vegetated shores with non-mobile substrates (C3.7) OR Sedge and reedbeds, normally without free-standing water (D5) OR Riparian and floodplain gallery woodland, with *Alnus, Betula, Populus* or *Salix* (G1.1/2/3) (*only if with water-fringing vegetation otherwise set Dispersal)	≥ 10 (10-100)	breeding and survival patches mosaic > 1 ha within the distance of 500 m (including the case of one Breeding/Survival Patch >1 ha)	≥ 100
Dispersal	Covers AS for Breeding Class BUT area <0.05 ha OR Covers AS for Survival Breeding Class BUT area <0.5 ha OTHERWISE Semi-open grassland (mesic, dry) (E1, E2) OR Woodland fringes and clearings and tall forb stands (E5.1/2) OR Sparsely wooded grasslands with trees/bushes (30-50%) (E7.2, F3.1) Gardens and allotments with trees/bushes, hedgerows (FA.3/4 OR Shrub plantations (FB.4) Deciduous forest (G1.6/7/B/D) OR Early-stage natural and semi-natural woodlands (G5.1/2/4/5/6/7/8) OR Mixed coniferous and deciduous forest (G4.5/6/8/B/F) OR Mixed crops of market gardens and horticultures (I1.2) OR intensive unmixed cultivated land (arable land, allotment without trees/bushes) I1.1/3/5 OR Ornamental and domestic garden areas (I2.1/2) OR	Likely some RU	total area of breeding/survival/dispersal patches cover > 60%	Likely some RU
Unsuitable	Sparsely developed land without trees/bushes OR mature coniferous forest (moist, mesic) (G3.1/4/7/F) OR Bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats H2/3 OR open water > 150 m off shoreline OR Agricultural constructions (structures connected with agriculture or horticulture (including greenhouses) J2.2 OR Highly artificial non saline running waters J5.4			
Hostile	Developed land with no or sparse vegetation (0-30%), constructed, industrial and other artificial habitats (J)			

Tab. 5.8 Classification rule set for Red-backed shrike *Lanius collurio*

Shrike	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area ≥ 10 ha AND Sparsely wooded grasslands with trees/bushes (E5.2/4*, E7.2*) OR open grassland (mesic, dry) (E2.2/3/7*, I1.5*) OR Moist grassland, seasonally wet and wet grasslands (E3.1/3/4/5*) OR Hedgerows (FA.3/4**) OR Small deciduous woods (G5.1/2/4/5/6/7/8*) * with thorny shrubs (>5%) **with density 2.5 km/km^2 or width > 15 m[a]	≥ 3	at least one Breeding patch mosaic >40 ha OR mosaic of Breeding and survival patches within < 500 m with a total area > 40 ha	≥ 12
Survival	Covers AS ABOVE BUT Area <10 ha and >3 ha OTHERWISE Area ≥ 3 ha AND Temperate and mediterranean-montane scrub (F3.1) OR arable land with low intensity agricultural methods I1.3 OR Mixed crops of market gardens and horticulture (I1.2)	≥ 1	Breeding and/or survival patches mosaic within 500 m, with total area >10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 3
Dispersal	Covers AS ABOVE BUT Area <3 ha, OTHERWISE Agriculturally-improved, re-seeded and heavily fertilised grassland, including sports fields and grass lawns (E2.6) OR Anthropogenic herb stands (E5.1) OR Shrub plantations (fruit, vineyards) (FB.4, G1.D) OR Deciduous forest (G1.1/2/3/6/7/B) OR Mixed coniferous and deciduous forest (G4.5/6/8/B/F) OR Intensive unmixed crops (I1.1) OR Riverine and fen scrubs (F91/2) OR poor fens and transition mires (D2.3) OR - Littoral zone of inland surface waterbodies (C3.1/2/3/4/5/6/7) OR Anthropogenic herb stands (E5.1) OR Cultivated areas of gardens and parks (I2.1/2) OR Agricultural and horticultural waste (J6.4)* (possible feeding source)	Unlikely some individuals	Dispersal/survival/breeding patches cover >60% of total area	Likely some individuals
Unsuitable	Surface standing waters (C1.2/3) OR mature coniferous forest (moist, mesic) (G3.1/4/7/F OR bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats (H2/3) OR Surface running or standing waters (C2.1/2/3/5) OR Low density buildings, Scattered residential and rural buildings (J2.1/2/3/4/6/7) OR Pavements and recreation areas (J4.6) OR Highly artificial man-made waters (J5.4) OR Waste deposits (J6.1)		Otherwise	
Hostile	Buildings of cities, towns and villages (J1) OR Extractive industrial sites (J3) OR Transport networks (J4)			

Tab. 5.9 Classification rule set for Hedgehog Erinacaeus europaeus

Hedgehog	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area ≥ 5 ha AND Open grassland (mesic, dry) (E2.2/3/6) OR Sparsely wooded grasslands with trees/bushes, hedgerows (E7.2, F3.1, FA.3/4) OR Woodland fringes (E5.2/4 OR Mixed crops of market gardens and horticulture (I1.2) OR Abandoned arable land (I1.5) OR Cultivated areas of gardens and parks (I2.1/2) OR Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7/8)	≥ 3	At least Breeding patch mosaic > 40 ha OR mosaic of survival and breeding patches within the distance of 1500 m with a total area >40 ha	≥ 28
Survival	Classes AS ABOVE BUT Area <5 ha and >2 ha OTHERWISE Area ≥ 2 ha AND Anthropogenic herb stands (E5.1) OR Fruit and nut tree orchards (G1.D) OR Moist grassland, seasonally wet and wet grasslands (E3.1/3/4/5) OR Cemetery (J2.2)	≥ 1	Survival and/or breeding patches mosaic within < 1500 m with a total area > 10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 7
Dispersal	Classes AS ABOVE BUT Area <2 ha OTHERWISE Mixed coniferous and deciduous forest (G4.5/6/8/B/F) OR - Deciduous forest (G1.1/2/3/6/7/B) OR Base-rich fens and calcareous spring mires (D2.3) OR Intensive unmixed crops (I1.1-3) OR Scattered residential and rural buildings (J2.1/2/6) OR Agricultural constructions (J2.4) OR Shrub plantations (fruit, vineyards) (FB.4) OR Littoral zone of inland surface water bodies (C3.1/2/3/4/5/6/7) OR Riverine and fen scrubs (F9.1/2) OR mature coniferous forest (moist, mesic) (G3.1/4/7/F)	Likely some individuals	Dispersal/survival/breeding patches cover >60% of total area	Likely some RU
Unsuitable	Bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats (H) OR Surface running or standing waters (C1.1/3,C2.1/2/3/5, D2.2) OR Pavements and recreation areas (J4.6) OR Highly artificial man-made waters (J5.4) OR Waste deposits (J6.1/4)		Otherwise	
Hostile	Buildings of cities, towns and villages (J1.1/2/3/4/6) OR Rural industrial and commercial sites (J2.3-4-5-7)Extractive industrial sites (J3.2/3) OR Transport networks (J4.1/2)			

Tab. 5.10 Classification rule set for Nuthatch Sitta europaea

Nuthatch	***Patch Habitat suitability***	***Carrying capacity (RU)***	***Unit Habitat suitability***	***Carrying capacity (RU)***
Breeding	Area ≥ 5 ha AND Mature coniferous forest (G3.1/4/7/F*) OR Mature mixed coniferous and deciduous forest (G4 G4.5/6/8/B/F*) OR Mature deciduous forest (G1. 1/2/3/6/7/B*) *with suitably sized trees: big oaks > 35 cm diameter at breast height otherwise deciduous trees (beech, elm, aspen, ash, birch) with >25 cm or mixed forest with conifers (trees >35 cm) with trunks and/or with hazel, chestnut	≥ 8	At least one breeding patch >40 ha OR survival and/or breeding patches mosaic (considering also patches outside the unit) within < 1500 m with a total area > 40 ha	≥ 40
Survival	Covers AS ABOVE BUT Area <5 ha and >2 ha or OTHERWISE Area ≥ 2 ha AND Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7/8*) OR Coniferous forest (G3*) OR Mixed coniferous and deciduous forest (G4*) OR Deciduous forest (G1*) *with some suitably sized trees (>30 cm including conifers)[a]	≥ 2	Breeding and/or survival patches mosaic within < 1500 m with a total area > 10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 8
Dispersal	Covers AS ABOVE BUT Area <2 ha OR AS ABOVE BUT without suitable sized trees OTHERWISE Hedgerows (FA.3/4) OR Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7/8) OR Fruit and nut tree orchards (G1.D) OR Sparsely wooded grasslands with trees/bushes (E7.2, F3.1) OR Cultivated areas of gardens and parks (I2.1/2) OR Woodland fringes and clearings and tall forb stands (E5.1/2/4) OR Riverine and fen scrubs F9.1/2 OR Shrub plantations (fruit, vineyards) (FB.4)	Unlikely	Dispersal/survival/breeding patches cover >60% of total area	Likely some individuals
Unsuitable	Bedrock, unvegetated or sparsely vegetated habitats (H2,H3) OR Open grassland (mesic, dry) (E2.2/3/6/7, E3.1/3/4/5) OR Littoral zone of inland surface waterbodies (C3.1/2/3/4/5/6/7) OR Mixed crops of market gardens and horticulture (I1.2-3) OR Intensive unmixed crops (I1.1/5) OR Surface running or standing waters (C1.1/3,C2.1/2/3/5, D2.2) OR Buildings of cities, towns and villages (J1.1/2/3/4/6) OR Rural industrial and commercial sites (J2.3-4-5-7) OR Pavements and recreation areas (J4.6) OR Highly artificial man-made waters (J5.4) OR Waste deposits J6.1/4		Otherwise	
Hostile	Extractive industrial sites J3.2/3 OR transport networks J4.1/2/3			

Tab. 5.11 Classification rule set for Hazel Dormouse *Muscardinus avellanarius*

Dormouse	***Patch Habitat suitability***	***Carrying capacity (RU)***	***Unit Habitat suitability***	***Carrying capacity (RU)***
Breeding	Area ≥ 5 ha AND deciduous forest (G1. 1/2/3/6/7/B*) OR coppice, overgrown hedgerows (G5.1/2/4/5/6/7*, FA.3/4*) *with oaks, elms and beech and/or hazel, that maintain a thick layer of scrub plants and underbrush	≥ 20	At least one breeding patch >20 ha OR Survival and breeding patches mosaic within < 150 m with a total area > 20 ha	≥ 100
Survival	Classes AS ABOVE BUT Area <5 ha and >2 ha OTHERWISE Area ≥ 2 ha AND Coniferous forest (G3*) OR mixed coniferous and deciduous forest (G4*) OR deciduous forest (G1*) OR Hedgerows (FA*) OR Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7*) *some suitably sized trees (>30 cm)	≥ 4	survival and/or breeding patches mosaic within < 150 m with a total area > 10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 50
Dispersal	Classes AS ABOVE BUT Area <2 ha OR AS ABOVE BUT without suitable sized trees OTHERWISE Thermophile woodland fringes (E5.2) OR Sparsely wooded grasslands with trees/bushes (10-30%) (E7.2, F3.1) OR Temperate thickets and scrub (F5.1) OR Riverine and fen scrubs (F9)	Likely some individual s	Dispersal/survival/breeding patches cover >60% of total area	Likely some individuals
Unsuitable	Inland surface waters (C1-2) OR Transition mires and quaking bogs (D2.3) OR Seasonally wet, wet, mesic grassland, meadow (E2, E3, E5.1-3-4-5) OR Cultivated areas of gardens and parks (I2.1/2) OR Shrub plantations (fruit, vineyards) (FB.4) OR Fruit and nut tree orchards (G1.D) OR Open grassland (mesic, dry) (E1, E2, I1.5) OR Moist grassland, seasonally wet and wet grasslands (E3) OR Littoral zone of inland surface waterbodies (C3) OR Arable land and market gardens (I1) OR Bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats (H)		other cases	
Hostile	Constructed, industrial and other artificial habitats (J)			

5.4.2. Habitat suitability at Patch level

The habitat suitability assessment provided a “landscape model” for each target species, as shown in the following figures (Fig. 5.3). Each landscape model shows different habitat suitability as perceived by species. For species representing the same habitat types (wetland, grassland and woodland) the landscape model appear very similar. Conversely, between species representing different habitats the differences are meaningful. In effect, no statistical correlation exist between habitat suitability for different species (as shown in Annex V). Summarizing, the landscape models, related to different species communities, are complementary; this confirms the species set is effective in likely representing all the ecosystems of study area.

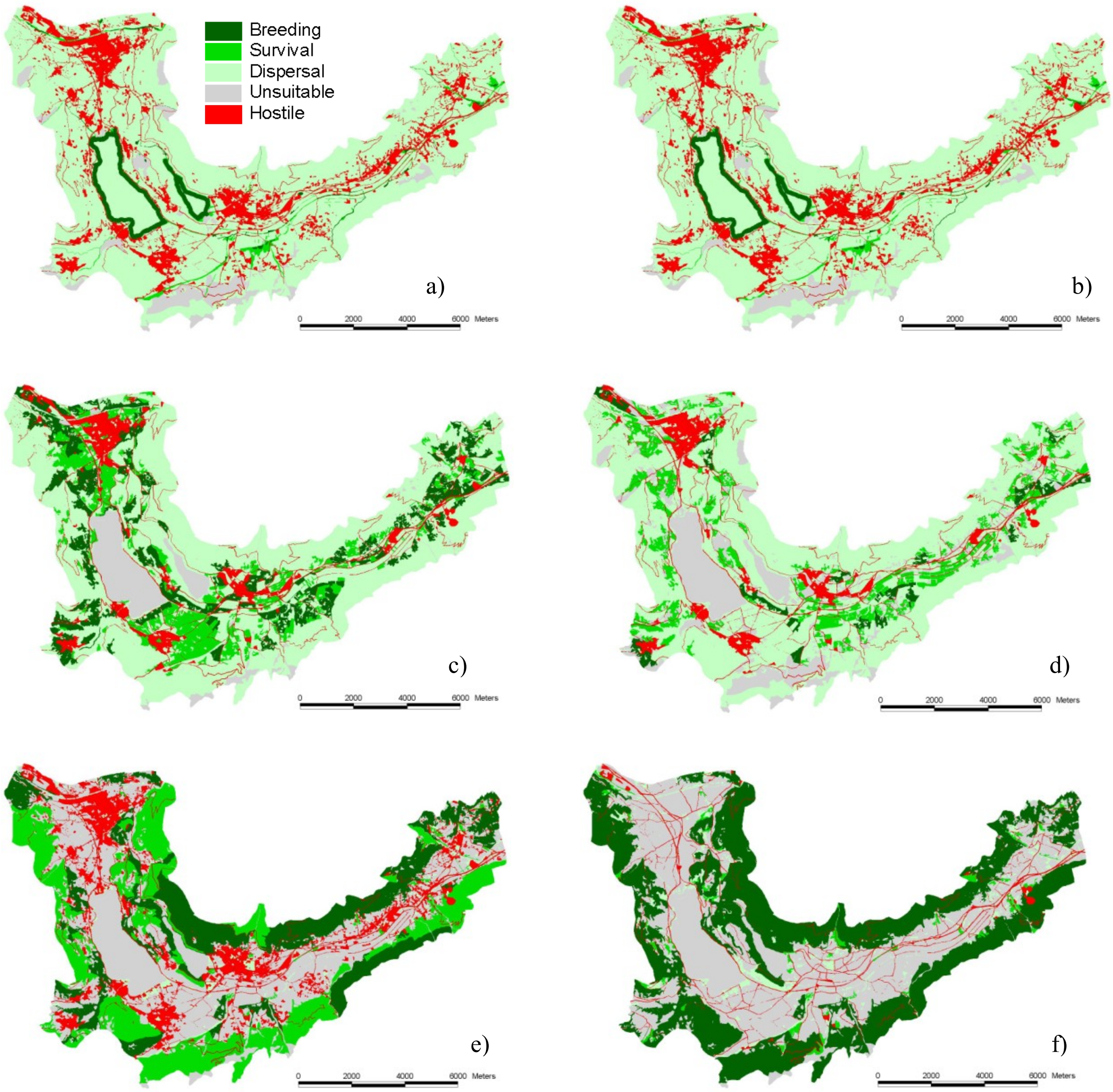


Fig. 5.3 Patch-Habitat suitability for: a) Ediblefrog, b) and for Damselfly, c). Hedgehog, d) Red-backed Shrike, e) Dormouse, f) Nuthatch.

The assessment also provided a quantification of habitat suitability in terms of amount of suitable area for different target species, the results are shown in Fig. 5.5 and Tab. 5.12. The study area seems to provide large amount of habitat for woodland species, while for the other species the study area supplies large “dispersal” areas, with limited habitat suitability. The most suitable areas for grassland are based on heterogeneous cultivated areas and small anthropogenic woods. The difference between “Hedgehog” and “Red-backed Shrike” landscape model is due to that hedgehogs require smaller areas than shrikes (which also require grazed pastures and meadows with thorny shrubs). The wetland species are supported mainly by lakes, few pools and sparsely vegetated shores of stream and ditches.

The highly valued areas are overlapping to SACs, as shown in Fig. 5.4; this corroborates the reliability of habitat suitability analyses. Again, the landscape models display suitability habitat areas even outside the nature reserves; this may contribute in decision making about the future composition of territory, as shown in the next chapter.

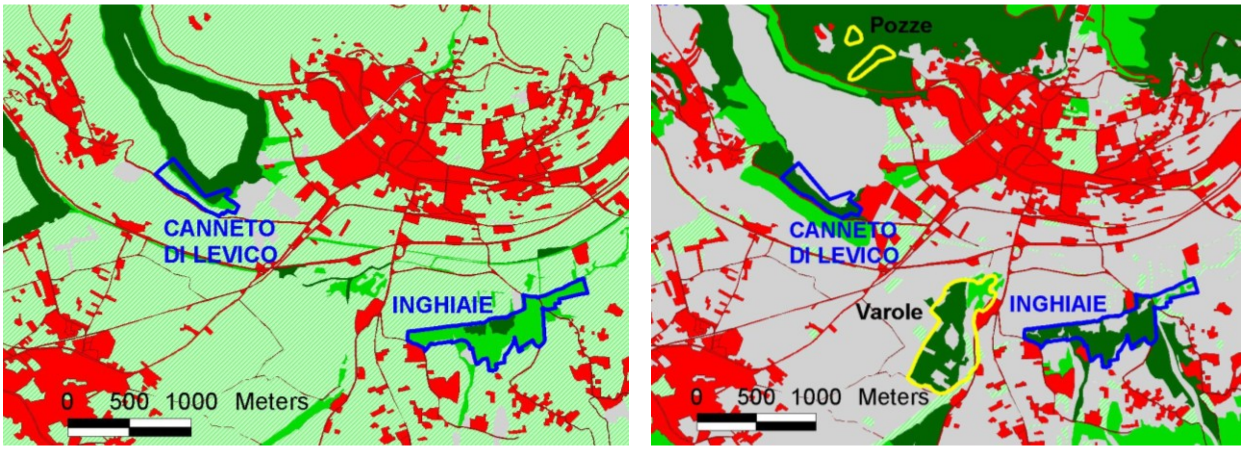


Fig. 5.4 Relations between habitat suitability and local nature reserves: left) habitat for EdibleFrog and a SACs; right) habitat for Dormouse and municipal areas of conservation (not protected).

On the other hand, the habitat suitability for Ediblefrog, Nuthatch and Dormouse may be overvalued. Concerning the amphibians the overvaluing may be primarily due to assessment of ditches and lakes. The ditches, within the study area, are environments may change every year, thus their suitability as a habitat for amphibians is unsteady. Their suitability is highly dependent on local and temporary conditions, like pioneer vegetation on the artificial banks, amounts and variation of water flow (Ficetola and De Bernardi 2004b). The lakes of Caldonazzo and Levico may entail uncertain assesmsent too. These environments may provide large suitable areas but the disturbance caused by tourism activities and the presence of fishes affect heavily the occurrence of amphibians (Ficetola and De Bernardi 2004b). These environment would require a site-by-site investigation of the remnant sparse water-fringing vegetation.

Concerning the woodland species, their occurrence is generally related to the amount of dead wood, especially for Picidae group as Nuthatch (Bellamy et al. 1998) and to richness of shrub species, for small mammals as Dormouse (Bright et al. 1994). These variables are not really surveyed for study area, but only verified locally and deduced from the land cover type. Concluding, the green and dark green areas depicted by the landscape models (Fig. 5.3) show necessary but not sufficient conditions for species occurrence.

Tab. 5.12 Habitat Function areas for target species.

Patches	Ediblefrog		Damselfly		Hedgehog		Shrike		Dormouse		Nuthatch	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Breeding	284.03	*2.7*	295.90	*2.8*	1413.76	*13.4*	318.90	*3.0*	2098.66	*19.8*	4461.40	*42.2*
Survival	168.0	*1.6*	190.7	*1.8*	1182.3	*11.2*	1221.1	*11.5*	2669.0	*25.2*	277.7	*2.6*
Dispersal	8106.1	*76.6*	8071.6	*76.3*	6251.4	*59.1*	6371.8	*60.2*	353.6	*3.3*	539.3	*5.1*
Unsuitable	574.3	*5.4*	574.3	*5.4*	889.1	*8.4*	1889.0	*17.9*	3979.2	*37.6*	4966.7	*47.0*
Hostile	1443.3	*13.6*	1443.3	*13.6*	839.1	*7.9*	775.0	*7.3*	1475.3	*13.9*	330.6	*3.1*

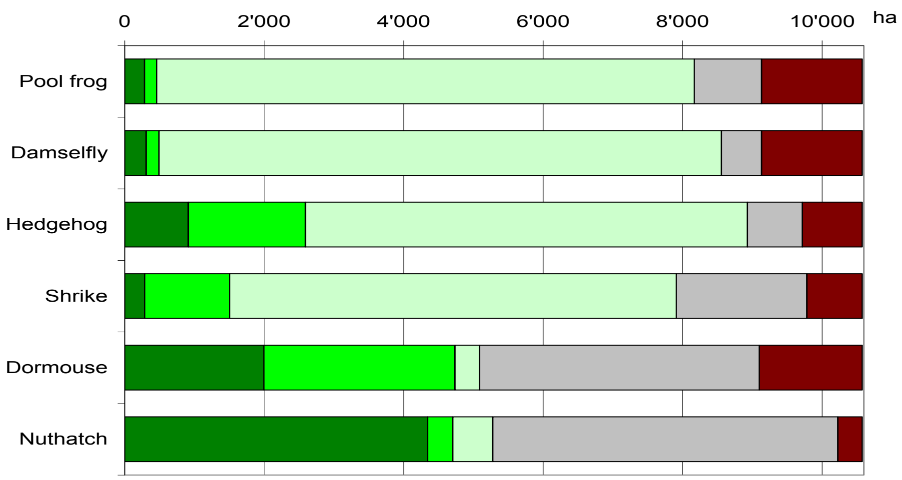


Fig. 5.5 Habitat suitability classification of study area.

5.4.3. Habitat potentialat Unit level

The habitat functioning, at Unit level, is shown in figures below, in Fig.5.6. Besides the lakes, springs, little ponds and littoral zones of temporary running waters supply breeding Unit for wetland species. The environmental heterogeneity of valley floor support breeding areas for grassland species. Woodlands on hillsides provide ample breeding areas for the woodland species, as one could expect from the Patch level analysis.

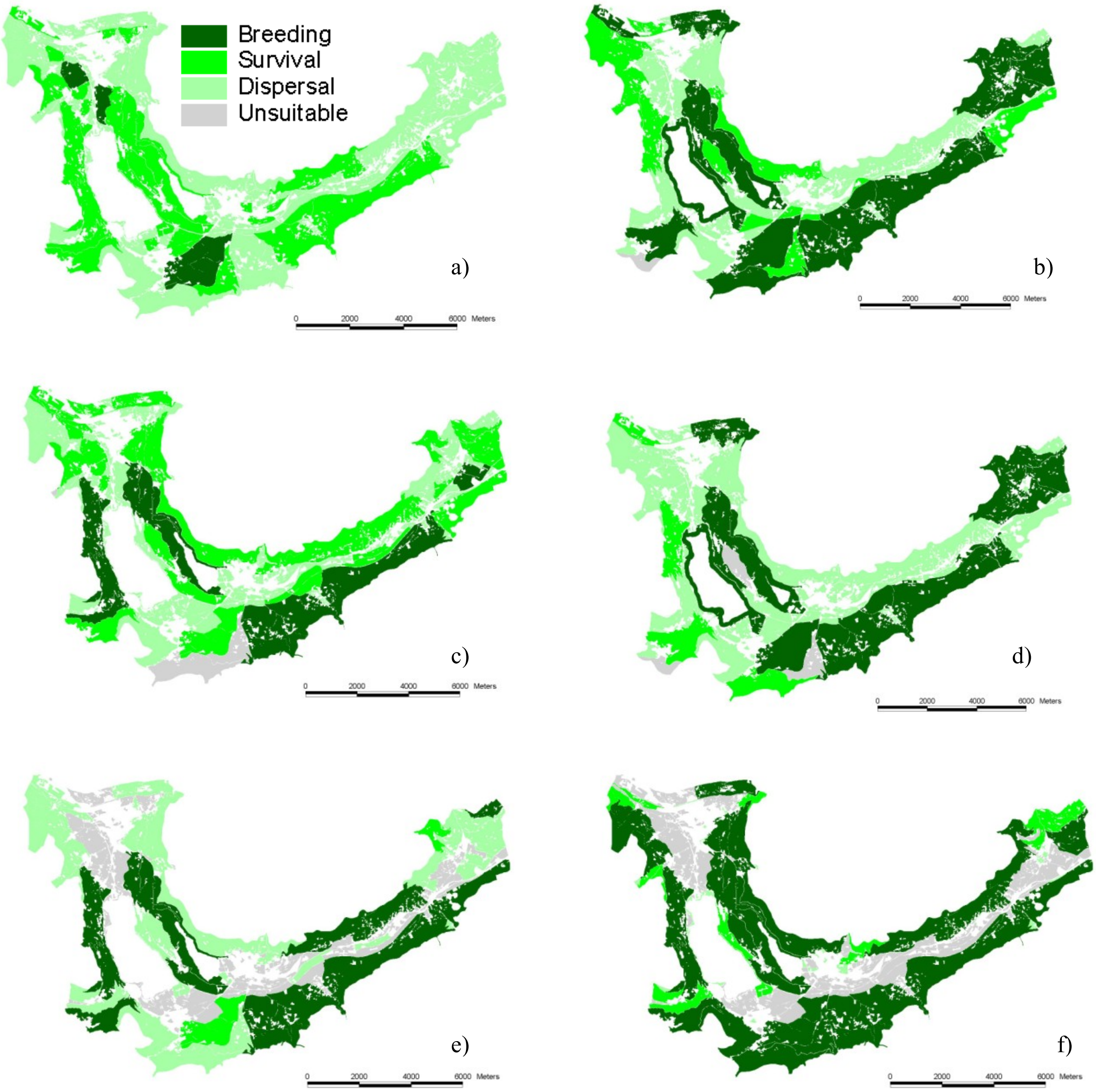


Fig. 5.6 Unit-Habitat potentialfor: a) Ediblefrog, b) Damselfly, c) Hedgehog, d) Red-backed Shrike, e) Dormouse, f) Nuthatch.

Unit Carrying Capacity for each species is presented in Fig. 5.7. In particular, thresholds of map legends are related to the expected number of RU for stepping stone and Key Population/Key Area. As shown, none of Units seems to support key population for grassland species, requiring at least 40 RU. This means that the populations living in the study area likely depend on immigration fluxes from outside areas.

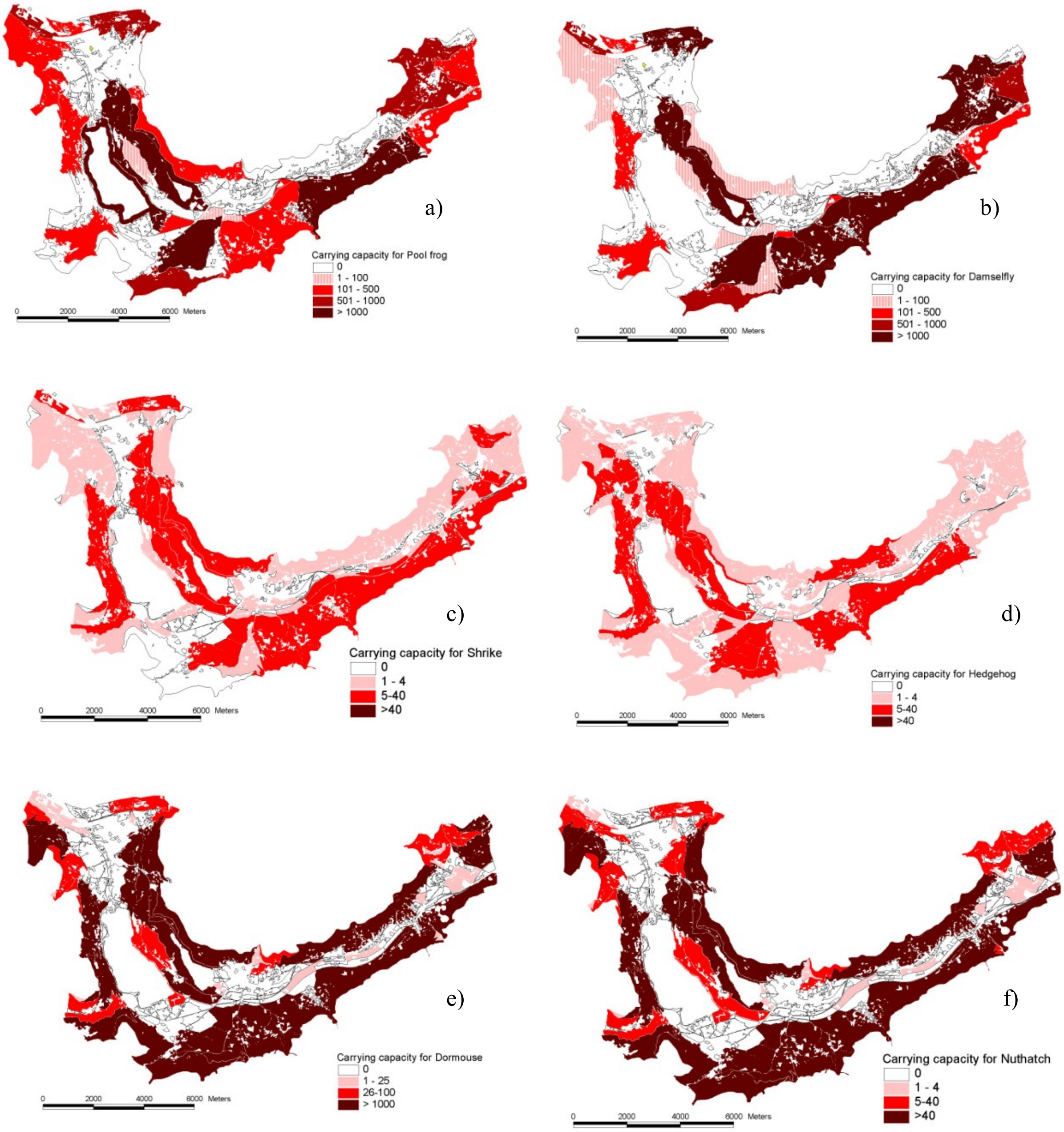


Fig. 5.7 Unit Carrying Capacity for: a) Ediblefrog, b) Damselfly, c) Hedgehog, d) Red-backed Shrike, e) Dormouse, f) Nuthatch.

5.5. Functional connectivity

5.5.1. Selection of target species

According to the indications of § 4.4.1, the following species were selected: Hazel Dormouse (*Moscardinus avellanarius*), Hedgehog (*Erinaceus europaeus*), Badger (*Meles meles*), Roe deer (*Capreolus capreolus*)and Ediblefrog (*Rana synklepton esculenta*). This set includes the terrestrial species already considered for habitat potentialanalysis. The other species (badger and roe-deer) were selected in order to provide the experts useful references for barrier effect estimation, setting a more complete range of species sensitivity to fragmentation. These species were assumed represent the vagility of vertebrate terrestrial fauna of study area.

Tab. 5.13 Target species list.

Species	*Latin name*	Dispersal range
Hazel dormouse	*Muscardinus avellanarius*	50-100 m[a]
Ediblefrog complex	*Rana synklepton esculenta*	1-5 km[b]
Hedgehog	*Erinaceus europaeus*	1-4 km[c]
Roe deer	*Capreolus capreolus*	4-20 km[d]
Badger	*Meles meles*	5-15 km[e]

a: (Miller and Yahnke 2004); b: (Smith and Green 2005); c: (Doncaster et al. 2001); d: (Ramanzin et al. 2007); e: (Rosalino et al. 2005).

5.5.2. Barrier effect estimation and Fragmentation 3D map

In order to estimate the barrier effect of landscape a Delphi survey was performed. For this survey, Italian experts were selected by a “snow-ball sampling” method: each expert was asked to refer to another acknowledged and reliable expert. The first search of fauna experts focused on those who participated at International Landscape Ecology Congress 2007. Other contacts were obtained from mailing list “Vertebrati”, managed by CILEA (Consorzio Interuniversitario Lombardo per l'Elaborazione Automatica), which includes about 900 faunal Italian experts. Eventually, 25 experts were selected and participated voluntarily: most of them have published scientific papers in international journals; many have more than a decade of experience in fauna monitoring.

They were asked, by a questionnaire sent by email, to estimate the probability of barrier effect due to the landscape elements included in Tab. 3.2 (§ 4.4.2). The estimation considered two processes at the same time: the species perception of obstacle (e.g. high traffic road avoidance) and the probability of survival when passing through.

The Delphi survey consisted in two rounds of questionnaire. In the first questionnaire round 25 experts participated, in the second round 18 experts answered. In the second round, the questionnaire was slightly modified according to the experts' suggestions.
The selected experts have different level of experience and knowledge about the target species. Some experts have many years of experience in monitoring one particular species; other experts have general knowledge on species dispersal and experience not specialized on the target species. Thus, within analysis of questionnaires, the answers were distinguished following categories of expert such as, in order of increasing expertise: a) acknowledged by other experts, b) with recent field experience about species dispersal (e.g. species monitoring), c) with scientific publications about some of target species. In practice, one questionnaire filled by an expert classified in "c" category was considered three times (like as three questionnaires), one filled by an "b" expert category two times and one by an "a" expert category one time.
The results are presented, in the Tab. 5.14, by means of the median values of experts' judgments and the median absolute deviation, MAD, as error estimation. The summation of median values allows comparing the "barrier sensitivity" of the species; the summation of MAD values allows comparing levels of accordance between the estimations.

Tab. 5.14 Barrier effects, where: 5 = barrier likely impossible to pass through, 1 = insignificant barrier.

	Dormouse	Hedgehog	Badger	Roe Deer	Pool Frog
mur0307	2 ±1	5 ±0	1 ±0	1 ±0	4 ±1
mur0715	3 ±2	5 ±0	4 ±1	2 ±1	5 ±0
mur>15	4 ±1	5 ±0	5 ±0	4.5 ±0.5	5 ±0
acq<30	5 ±0	2 ±1	1 ±0	1 ±0	1 ±0
acqlen>30	5 ±0	4 ±1	3 ±0.5	1 ±0	1 ±0
acqvel>30	5 ±0	5 ±0	4.5 ±0.5	3 ±1	1.5 ±0.5
strd0	1 ±0	1 ±0	1 ±0	1 ±0	3 ±1
strd1	3 ±1	3 ±1	1 ±0	1 ±0	4 ±1
strd2	4 ±0	3 ±0	2 ±0	2 ±0	5 ±0
strd2+	5 ±0	5 ±0	4 ±1	4 ±1	5 ±0
parc100	2 ±1	1 ±0	1 ±0	2 ±1	2 ±1
ind100	5 ±0	4 ±0	2 ±1	4 ±1	5 ±0
udens100	4 ±0	3 ±1	2 ±1	4 ±1	5 ±0
urado100	3 ±0	2 ±1	2 ±1	2 ±0	4 ±0
parc1000	2 ±1	1 ±0	1 ±0	2 ±1	2 ±1
ind1000	5 ±0	5 ±0	4 ±0	5 ±0	5 ±0
udens1000	5 ±0	3 ±0	2 ±0	5 ±0	5 ±0
urado1000	4 ±1	2 ±0	2 ±1	3 ±1	4 ±1
Σ(mediane)|Σ(MAD)	**67|8**	**59|5**	**42.5|7**	**47.5|8.5**	**66.5|6.5**

These results show that Hedgehog has an intermediate "barrier sensitivity" (59) and the best accordance of expert judgment (±5). Dormouse and Badger are at the extremes of "barrier sensitivity" (67 against 42), both with rather differing judgement (8 and 7).

The estimated barrier effects were attributed to corresponding land-cover polygons. In some cases the barrier effect was adapted during the field surveys. For example, although the experts did not defined total barrier effect (at the worst case 99% of probability) a total barrier effect (100 out of 100 cases) was assigned to double-lane roads fenced by tall concrete walls or to those roads with concrete divider between lanes.

By ArcScene (ESRI), the barrier sensitivity attribute was embodied in a 3D scene as height of extrusion for land cover polygons, composing a **species-specific fragmentation map** (Fig. 5.8). This map illustrates the landscape fragmentation as perceived by the Ediblefrog. The same landscape element affect differently the species as shown by different heights of road-polygons, depending on their borders (e.g. only mile-stones or fences). A barrier effect is provided by urban area and roads but also by water bodies, as highlighted by the arrows. At the left of figure is Levico lake, in the centre the barrier is represented by a artificial banked ditch.

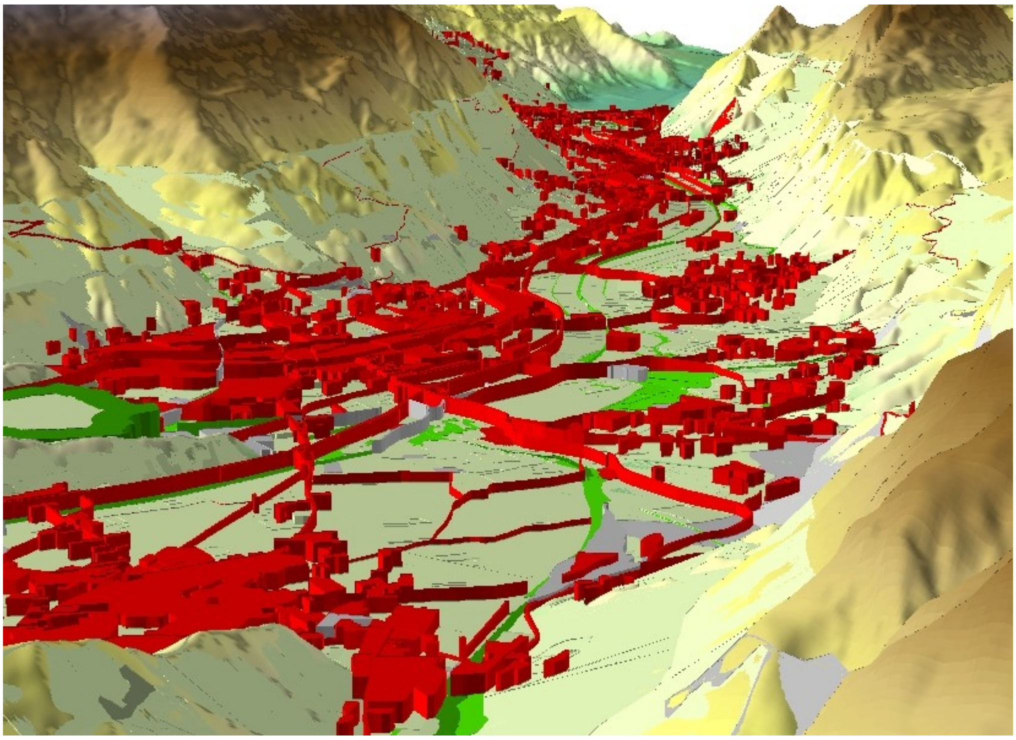


Fig. 5.8 Landscape barriers as perceived by Ediblefrog, colours are related to habitat suitability.

5.5.3. Graph of functional connectivity

The barrier effect estimation allows to define the linkages between Units, assuming the same probability of dispersal from Unit *i* to Unit *j* equal as from Unit *j* to Unit *i*. For each adijacent Unit it was calculated the edge-to-edge distance. This distance represents the trek that a species should cover through the matrix between two Units. All the connections between Units compose the **spatial graph of functional connectivity**. The Fig. 5.9 represents the connectivity of the Unit habitats for Ediblefrog.

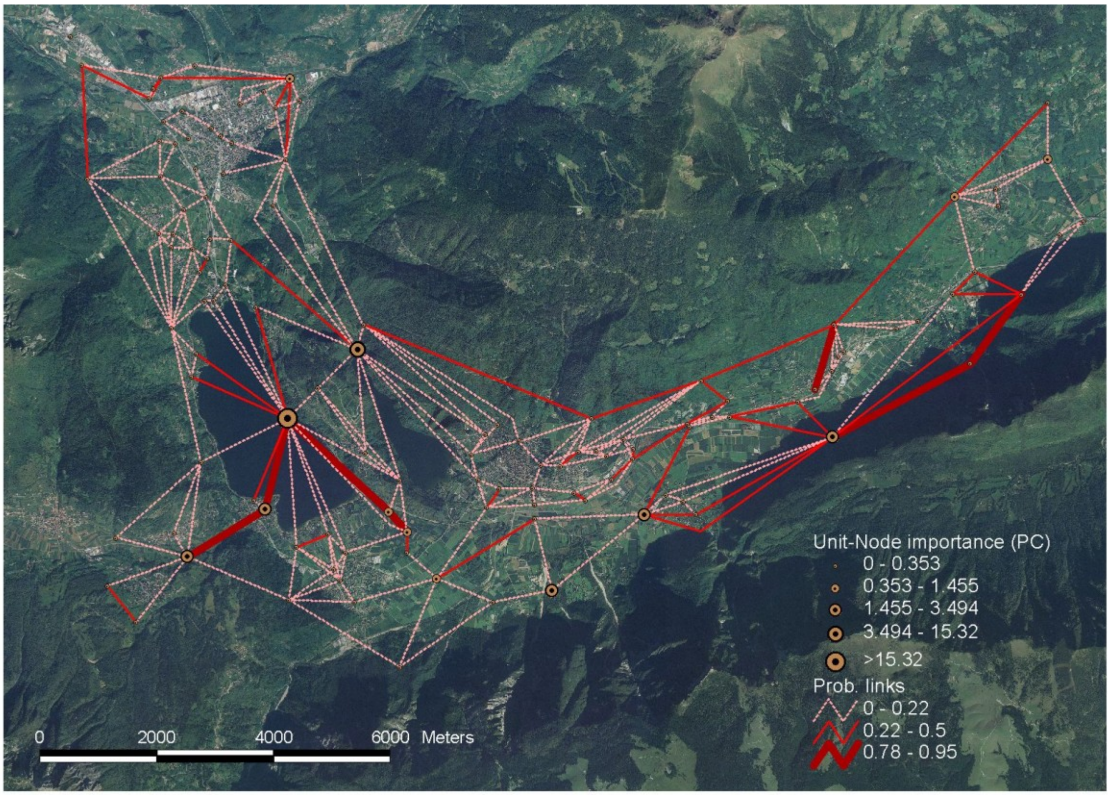


Fig. 5.9 The spatial graph representing the connectivity for amphibians.

Considering a threshold of 0.5 for “viable” connections, the graph is decomposed in graph components (Fig. 5.10). Considering only the Unit suitable to sustain (at least) a number of RU expected for a stepping stones, the graph components was reduced in “viable habitat network” (VHN). Therefore, the actual functional connectivity for Ediblefrog appears to be based only on 11 connected Units (of 223), belonging to 3 very short habitat networks (Fig. 5.10, right).

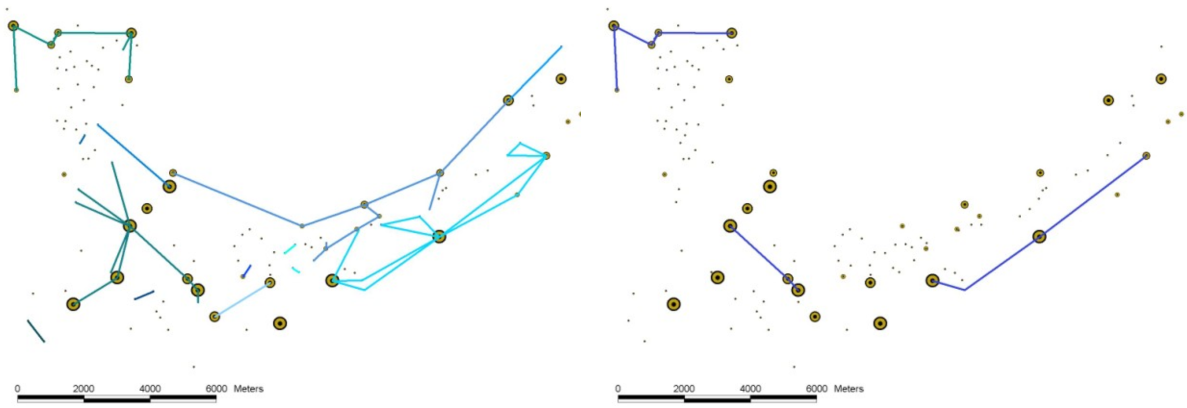


Fig. 5.10 Graph components for amphibians (right), graph components linking functioning habitats (right).

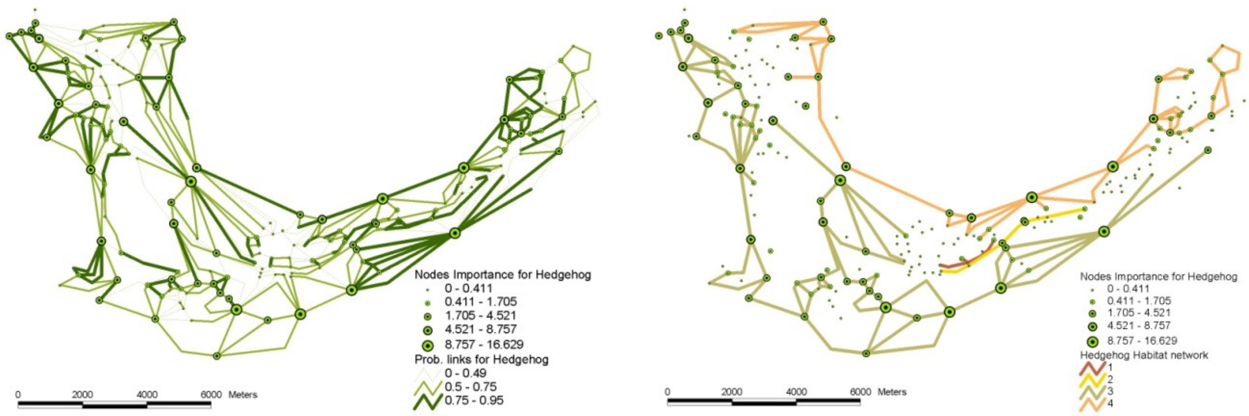


Fig. 5.11 Spatial graph for hedgehog (left), graph components for hedgehog.

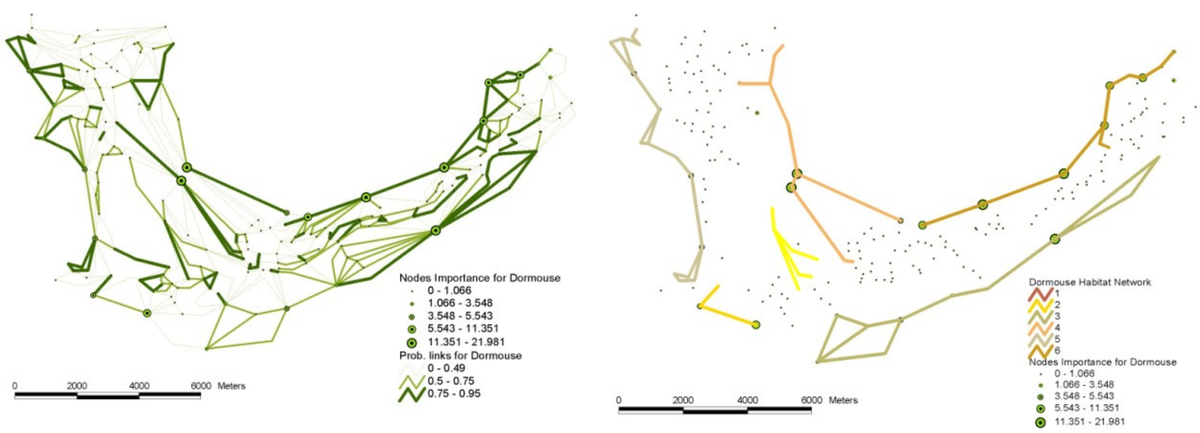


Fig. 5.12 Spatial graph for dormouse, graph components for dormouse.

For the woodland and grassland species the study area seems more connected, as shown in Fig. 5.11 and Fig.5.12. Many Units provide only negligible contribution to overall connectivity for Dormouse (see the many small circles). The study area provides only 6 viable habitat networks, with an average length of 7.3 nodes. For Hedgehog 4 longer viable habitat networks are available, with an average length of 25.5 nodes.

5.5.4. Unit Network functioning

The assessment of Unit Network functioning considered all Units included in viable habitat networks, summing their carrying capacity, comparing the Network Carrying Capacity (NCC) with the norm values for viable populations, as defined in Tab. 3.4 (see § 4.4.5). The functioning of habitat networks is shown in following figures.

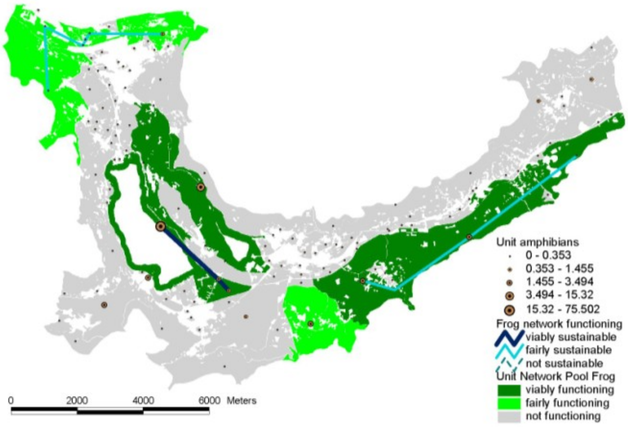


Fig. 5.13 Habitat potentialat Unit Network level for wetland species.

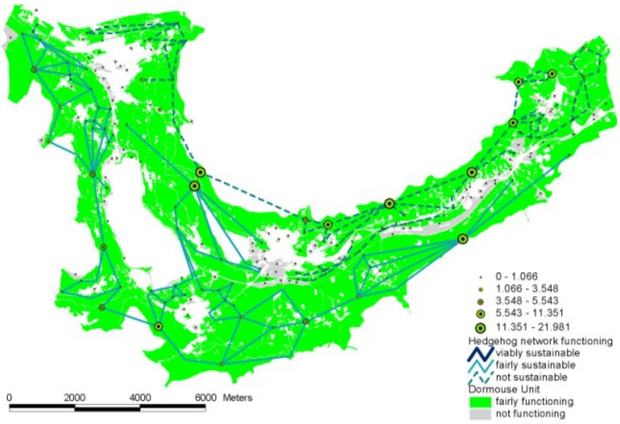


Fig. 5.14 Habitat potentialat Unit Network level for grassland species.

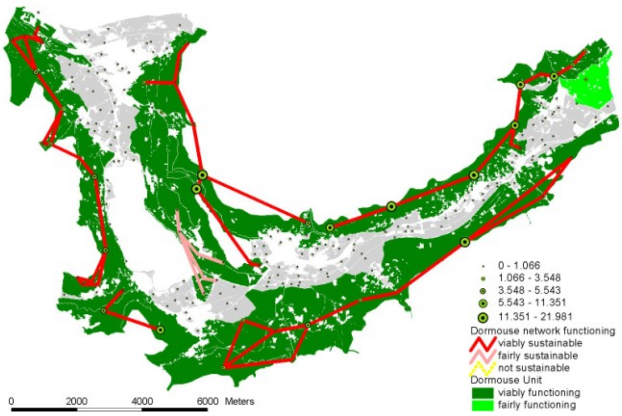


Fig. 5.15 Habitat potentialat Unit Network level for woodland species.

5.6. Ecological values

The results of the previous paragraphs were aggregated into "ecological value" in order to transform the species-specific assessments into value-based information (see § 4.5). The aggregation was performed in a bottom-up way according to a decision tree, where higher-level attribute depends on lower-level attribute. The decision rules entailed definition of "values" in terms of priority between qualitative categories (see some details in Annex VI). An ideal application would entail discussing and sharing the values definition with decision makers or other stakeholders. In fact, defining the rule of aggregation involves the definition of goals and priorities for biodiversity conservation.

Two scenarios of application are shown, considering two different conservation goals. In the first I assumed the aim of preserving local biodiversity as much as possible. Within this strategy all the habitats have the same importance (Tab. VI.4 in Annex VI). Thus, a "maximum rule" was applied for the aggregation of the species-based and habitat-based evaluations, the result is shown below, in the Fig. 5.16. "Very high" value, in this map, depicts areas whose loss would imply loss of habitat functions, or imply significant fragmentation effects for at least one species community, without distinguishing them.

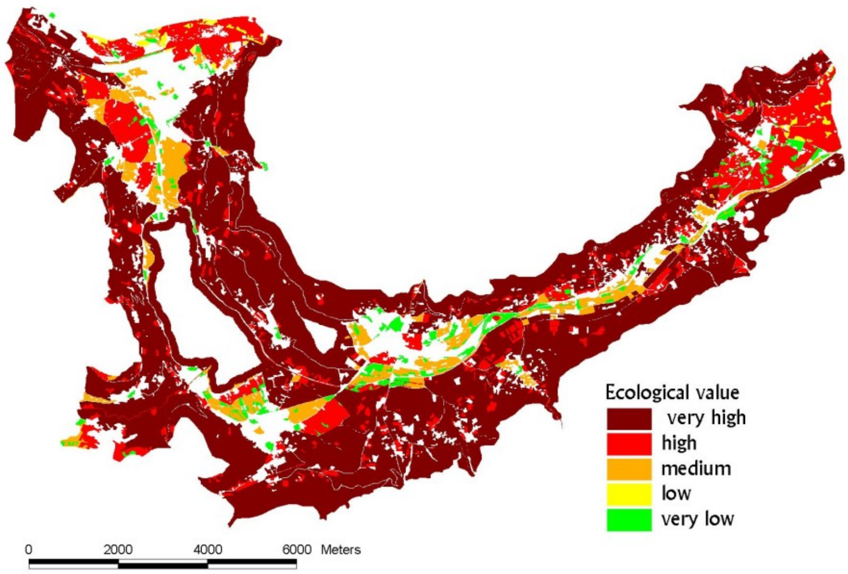


Fig. 5.16. Ecological value, according to the goal of preserving the local biodiversity as much as possible.

In the second scenario different priority among the habitats was assumed. In particular, wetland and grassland habitats were considered the most important. This choice may be justified by considering that woodlands are very common in study area and even increasing in Trento province; conversely grasslands and wetlands are suffering an increasing pressure by growing urbanization and decreasing at provincial scale. Thus, wetland and grassland could be considered actually vulnerable habitats, therefore, the most important. Operationally, a special kind of "maximum rule" was performed for Patch and Unit level, based only on wetland and grassland values and disregarding the woodland values (Tab. VI.5). According to this approach, the final ecological map resulted very different, as shown in Fig. 5.17.

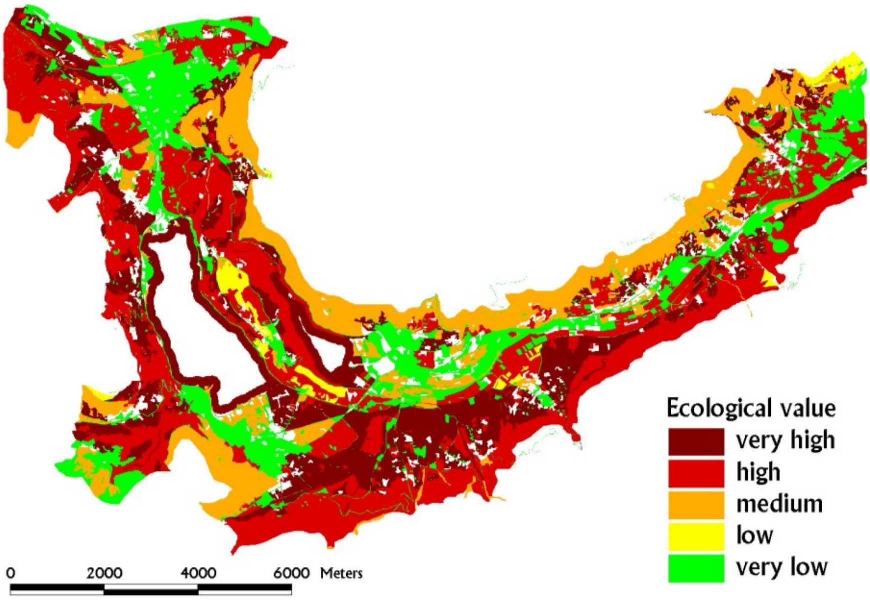


Fig. 5.17 Ecological value, by the assumption of priority for grassland and wetland habitats.

The dark red ("very high") areas provide essential habitat functions for both grassland and wetland communities. The "high" or "medium" areas are those that may provide "survival" patches and well connected areas for (at least) one species community. The "low" or "very low" are those areas that cannot provide enough habitat functions or that are actually isolated.

5.7. Concluding remarks

The methodology application has shown some strength points of the approach. According to Corry and Nassuer (2005) "to be useful tools for planners and designers, landscape (analyses) need to provide reliable results that validly imply something about ecological consequences even at finer scales, including narrow linear and small patch patterns, including the small patches of potential habitat associated with the roadsides, railways, field boundaries and property lines".

The assessment is essentially based on a detailed land-cover map and on habitat requirements of target species. The thematic resolution of the land cover map, by using third level of EUNIS legend, by digitalizing even the very small landscape objects (i.e. 2 m in width and 50 m^2 as area), allowed identifying habitats for small mammals (as Dormouse) and amphibians (as Ediblefrog). The hierarchical approach provided assessments on landscape functioning at multiple-scale. A site (Patch) can be evaluated considering its surrounding (Unit) and the habitat network to which it belongs (Unit network).

These facts prove the potential of proposed approach in supporting planners and designers. The information provided by habitat potentialassessment may support the design of ecosystem networks, or at least the awareness of the importance of certain areas, in order to preserve the possibility of developing ecosystem network in the future. For example, Core areas and stepping stone can be identified outside the protected areas, considering Breeding Patches and Breeding Units. The characterization of landscape barriers and the graph of functional connectivity show criticality for the landscape ecological functioning, but may also support the identification of areas for habitat restoration or loss compensation.
In addition, the approach is according to Forman's indications (1995) concerning the scale for landscape ecology investigations: "data resolution should be 2–5 times smaller than the phenomena of interest", "a minimum of three linkages (levels) must be known".
The methodology entails also an operational innovation in ecological assessment. The ecological value map (Fig. 5.17), though appears similar to the map resulted by SISA project (see § 2.3), is rather a dynamic tool. The difference concerns the allocation of values. Several sets of spatial queries, structured in a geodatabase, constitute a spatial model of properties emergent from structure, composition and functioning of the landscape. Once a land-cover change affects an area, or its functioning or its linkages with other areas, the ecological value will change not for that area but also for all ecologically related areas. Through this rule-based model it is possible to assess a kind of "response" of ecological attributes to an environmental impact. In other words, if we "remove" (e.g. by a project construction) or "divide" (e.g. by infrastructure development) some habitat patches, the updating of ecological value map (Fig. 5.17) will change the distribution of ecological values in all areas related to the construction site. On the contrary, the environmental value map resulted in SISA approach, after an area "removal" will show exactly the same distribution of ecological value exactly except for the modified site.
Obviously, the methodology has also limits. All the assessments concerning the barrier effect, the habitat potentialand the faunistic carrying capacity suffer from different degrees of uncertainty. As example, the appraisal about species population and their viability is purely based from landscape ecological considerations without species occurrence-data. Besides, population variations are complex and their dynamic can be influenced by factors others than the landscape in which they live. Consequently, the population estimations should be considered as population indicators rather than quantitative measures.
A concluding remark concerns the value-based information provided by qualitative multi-attribute evaluation. I set the decision rules for my own, making explicit the assumptions, but other priorities and values for a territory could be defined. Since the critical element of an evaluation is the reliability of the people involved in it, a panel of experts should be involved (Kontic 2000; Richey et al. 1985). Another related issue concerns goals for biodiversity conservation. What biodiversity the land manager is willing to maintain or

recover is a question that is rarely answered (Possingham et al. 2001). Different targeted biodiversity components, different amounts of habitats and different focuses for restoration efforts entail different evaluations for the same landscape. Thus, the "ecological value", and all related evaluations, should be shared with decision makers.

Chapter 6

Application of the methodology to support land-use planning

6.1. Introduction

The proposed methodology seems providing useful tools for planners and designers, as outlined previously. This chapter is meant to validate this hypothesis, showing a simulation of biodiversity impact of a planned land-use change and a real case of supporting a local master plan. In detail, the following paragraphs show an introductory assessment of habitat loss and habitat fragmentation potentially caused by master plans designed for the study area. Subsequently, a contribution to spatial planning for Roncegno municipality is presented, in terms of indications concerning vulnerable biodiversity components and proposals for operational strategy.

6.2. Habitat loss caused by land-use change

In the study area several master plans have been designed by different municipalities, some of plans are going to be renewed, as the case for Roncegno. Each project concerning the future shape of a landscape should consider the cumulative effects of all land-use changes, caused by the master plan itself, but also by land-use changes in nearby districts. Thus, I considered the mosaic of municipal master plans (update at 2004) covering whole the study area. This mosaic provides allocation of the next land-use, entailing new urban areas, as residential settlements or industrial sites and infrastructures. The definition of artificial covers (Tab. 6.1) was used in an impact simulation. This simulation allowed assessing the threats on biodiversity related to the master plan scenarios, in terms of habitat loss and habitat fragmentation.

Tab. 6.1 Land-uses designed by master plan, used in biodiversity impact simulation.

code	*Original definition*	*Planned land-use*
B01	Centro storico tradizionale	Historical urban center
B03	Area residenziale di recente impianto	Recent residential area
B04	Area di riqualificazione	Urban Riqualification
B05	Area commerciale	Commercial center
B07	Area alberghiera	Hotels
B09	Area per servizi socio-amministrativi e scolastci	Public services
B11	Area per servizi sportivi	Sport infrastructures
B13	Area per servizi infrastrutturali	Infrastructure
B15	Parcheggi	Parking
B16	Area produttiva zootecnica	Farms
B17	Area produttiva industriale artigianale	Industrial site
B18	Area mista produttiva e commerciale	Mixed industrial and commercial
B19	Area estrattiva	Quarry

The habitat loss assessment involved two approaches. The first approach consisted in an overlay-mapping, a common approach in many environmental assessments. In detail, a clipping operation was performed between the ecological value map (see § 6.6) and the master plans' mosaic.

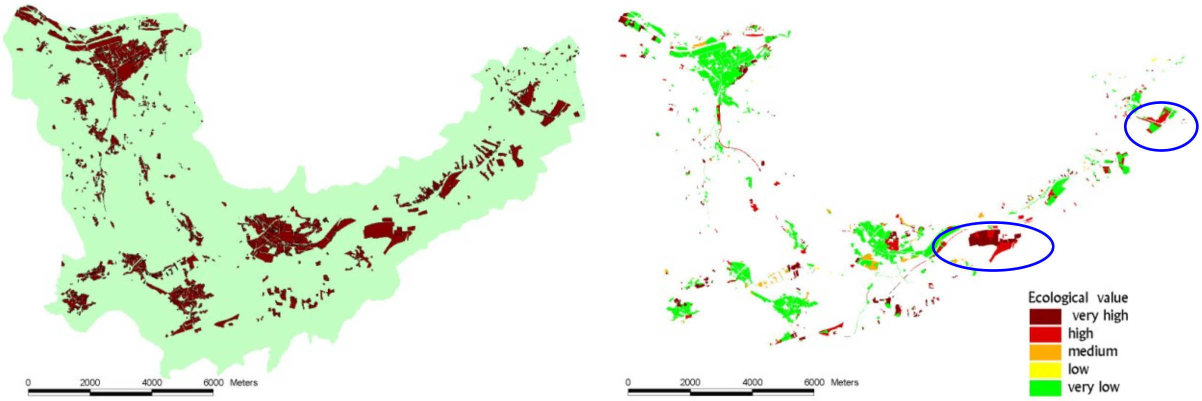


Fig. 6.1 Overlay mapping between Master plan mosaic (at right, dark red areas are forthcoming changes in land-use) and Ecological value map.

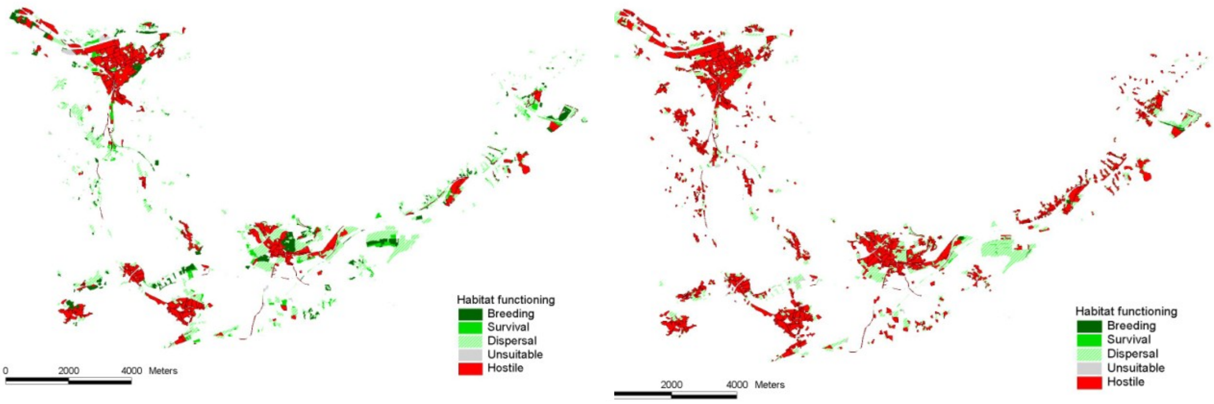


Fig. 6.2 Result of clipping the habitat potentialmap for Ediblefrog and Hedgehog.

The clipped areas (Fig. 6.1) were assessed by their specific value. The first result allowed quickly identifying the areas where the land-use change would affect more the habitats. In the case, some areas with high ecological value (Fig. 6.1Fig. 6.1), covered by grasslands and including some water bodies, would be affected. Moreover, the overlay-mapping provided a quantification of habitat loss for each species (Fig. 6.2). The clipped areas were assessed by their habitat functioning, in terms of lost hectares and reproductive units (RU) no more sustained (Fig. 6.3). The same land-use change would cause different impacts to different species. In the simulation, this would mainly concern the grassland species (Hedgehog, Red-backed Shrike).

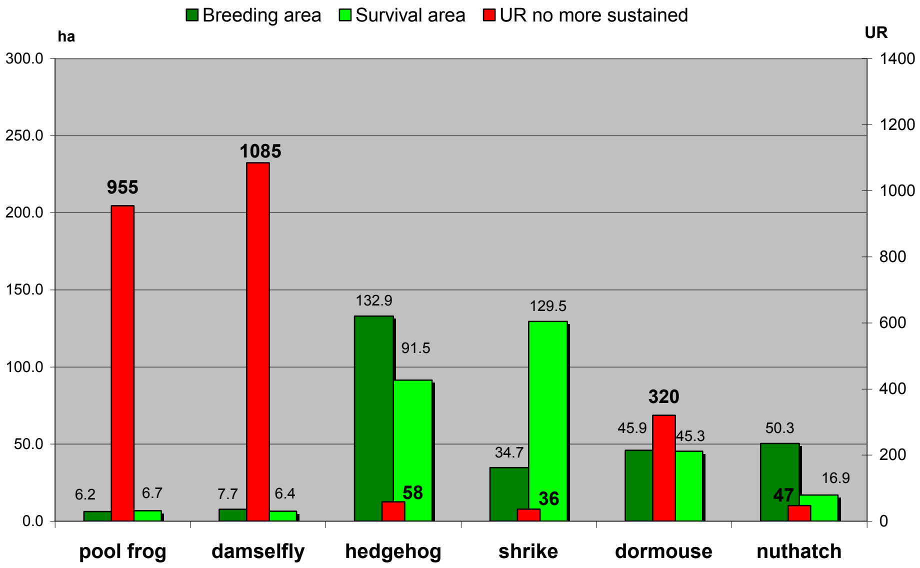


Fig. 6.3. Habitat loss as sum of land-use changes.

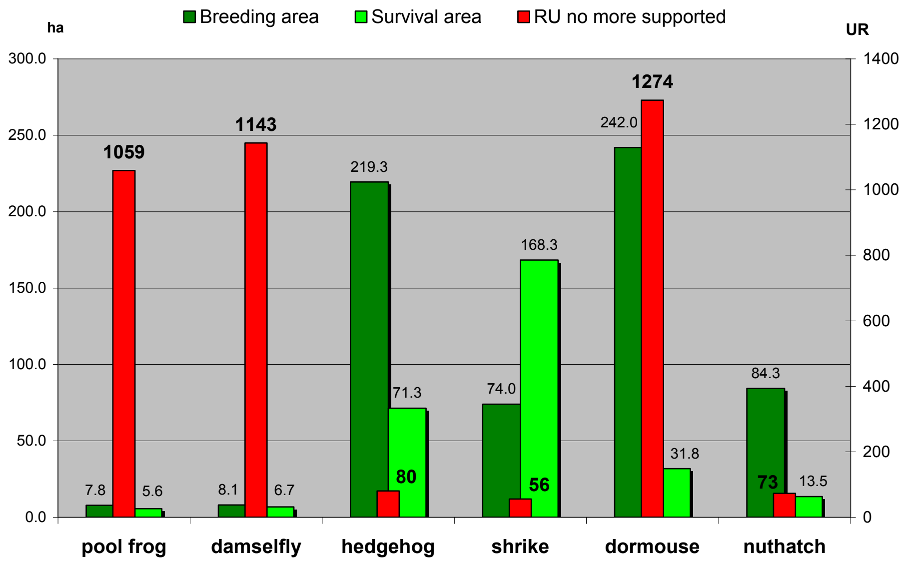


Fig. 6.4. Habitat loss as cumulative impact of land-use change.

The second approach involved updating the habitat potentialmaps within the master-plan scenario, and assessing the difference on the starting situation. This approach, as mentioned in the previous chapter, is quickly applicable by using a geodatabase that performs automatically the numerous rule sets (see Annex IV and Annex VI). This approach provided different results, especially considering the likely RU loss, i.e. the loss of capability to sustain territories or families (Fig. 6.4). The difference between two assessments is really meaningful, the second approach provided higher values of RU loss, namely: for Ediblefrog + 11%, Damselfy + 5%, for Hedgehog +38%, Red-backed Shrike + 54%, Dormouse + 298%, for Nuthatch + 55%. Again, to evaluate these losses the total amount of carrying capacity for the territory should be considered and compared.

Anyhow, the last estimation is more realistic than the former obtained by simple clipping. In fact, the overlay mapping operation may underrate the habitat loss, disregarding the spatial attributes of habitat functioning. Conversely, this functioning depends on area thresholds and on spatial relationships between the vegetation covers.
These estimations, although approximate, may suggest a carrying capacity and thresholds for the development of an ecologically sustainable landscape. In fact, any habitat loss, in a sustainable perspective, should be balanced by habitat restoration. The values shown above may indicate the amount and the quality of habitat that a municipality should restore or fund to compensate the habitat loss. As example, for the study area, the habitat restoration should provide an amount and quality of habitats able to sustain at least 1059 RU of Ediblefrog, 80 RU of Hedgehog or 56 RU of Red-backed Shrike (Fig. 6.4).

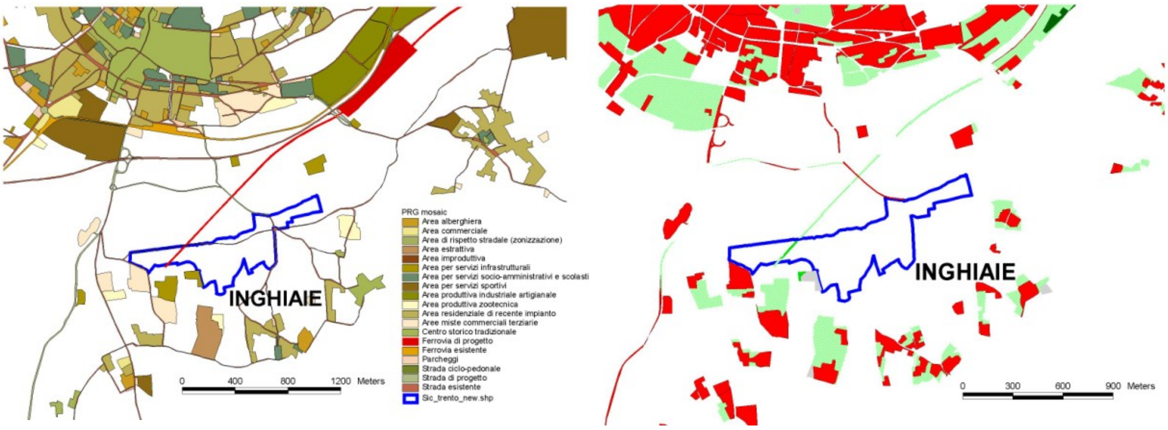


Fig. 6.5 Planned railway segment, relative expected habitat loss for Ediblefrog (by simple overlay-mapping).

Concerning habitat fragmentation the master plans' mosaic provides an illustrative example: a new segment railways is planned, in municipality of Levico. This project would affect a Special Area of Conservation, with an "incision" effect (Jaeger 2000a). If we consider only the amount of hectares potentially affected, serious impacts could be easily neglected (Fig. 6.5). On the other hand, the application of commonly used fragmentation indices, as division index or effective mesh size, would provide no meaningful insight about the ecological consequences.

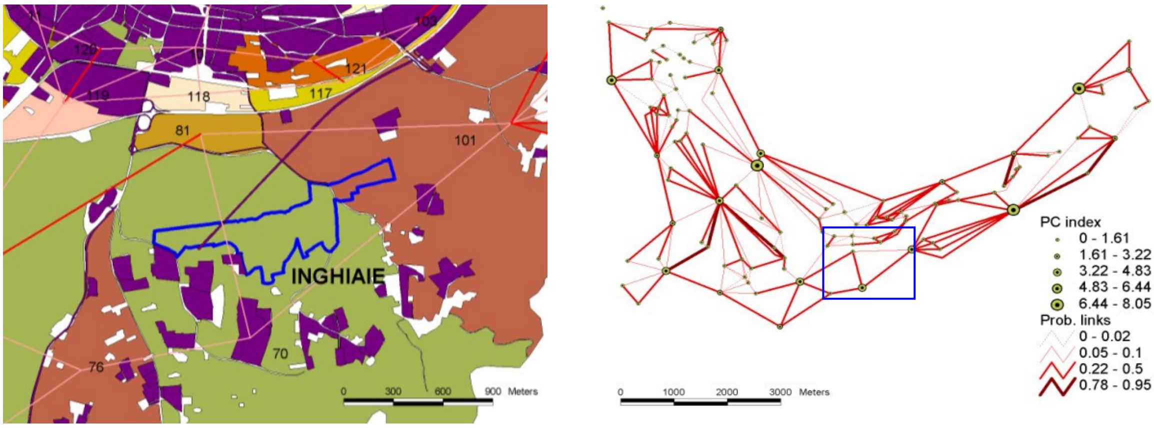


Fig. 6.6 Railway segment and the ecological relations between Units.

Otherwise, taking into account the spatial graph of connectivity it is possible to better understand the influence of the planned railway on connectivity of the whole valley floor. This understanding should involve the definition of project alternatives less affecting the functional connectivity especially for wetland species. Alternative design should consider different locations or at least project mitigations able to maintain bio-permeability of the infrastructure.

6.3. Indications for Roncegno spatial plan

The ecological characterization, presented in the previous chapter in terms of habitat value and connectivity value, may provide effective indications for spatial planning. These indications depend on specific ecological role of a certain area play in the valley system. These may be translated into operational strategies, especially in the stages of plan design. Proceeding into the details of each strategy more detailed analyses may be supported by the habitat potentialassessment, concerning specific biodiversity components.

According to the ecological characterization, Roncegno territory can be distinguished in two zones. The mountainside constitutes the first zone, covered mainly by woodland and with scattered traditional cultivation (meadows, chestnuts, domestic gardens). This zone supplies functioning habitats mainly for woodland species and effective connectivity inside and towards alpine pastures at higher belts. The second zone is located on the conoids at the valley floor, with gentler slopes, covered mainly by intensive cultivations. In this zone three types of habitat (grassland, wetland and woodland) coexist with urban areas and infrastructures. This zone appears rather fragmented and partially divided from the first.

The fauna biodiversity asset of Roncegno territory is represented mainly by woodland species (here, alpine ecosystems are neglected), supported by the habitats on the slopes and by the higher elevation areas (Fig. 6.7). The species communities related to grassland and wetland appear the more vulnerable, composed by few sub-populations in the lower and flatter zones of Roncegno (Fig. 6.8). Nevertheless, these species, requiring heterogeneous habitats, depend on human interventions on landscape. For these reasons the assessments particularly focused on them.

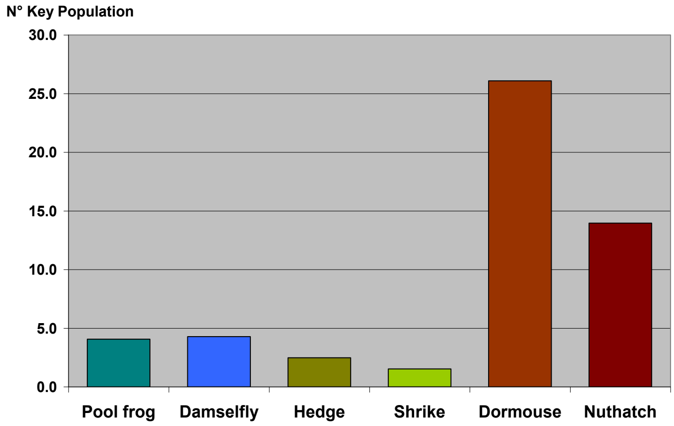


Fig. 6.7. Expected number of sub-populations supported by municipal territory.

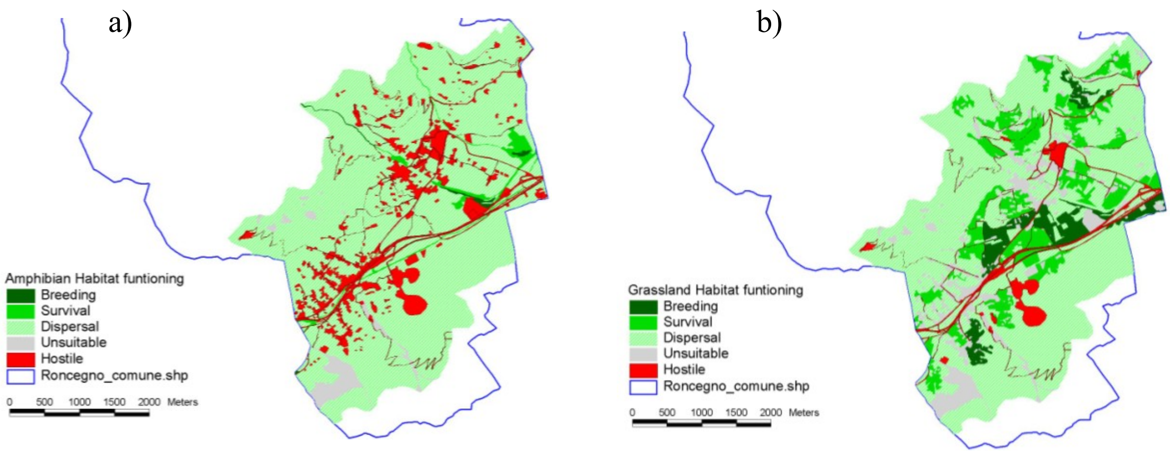


Fig. 6.8. Habitat potentialmaps: a) for wetland species, b) for grassland species.

Specifically, the habitat maps and the spatial graph of connectivity ground some general indications concerning conservation priorities and restoration actions. As example, main directions of possible dispersal flow (green arrows Fig. 6.9) and critical gaps (for grassland and wetland species) can be depicted. These allow defining priorities for conservation, in order to guarantee the connectivity along the valley floor.

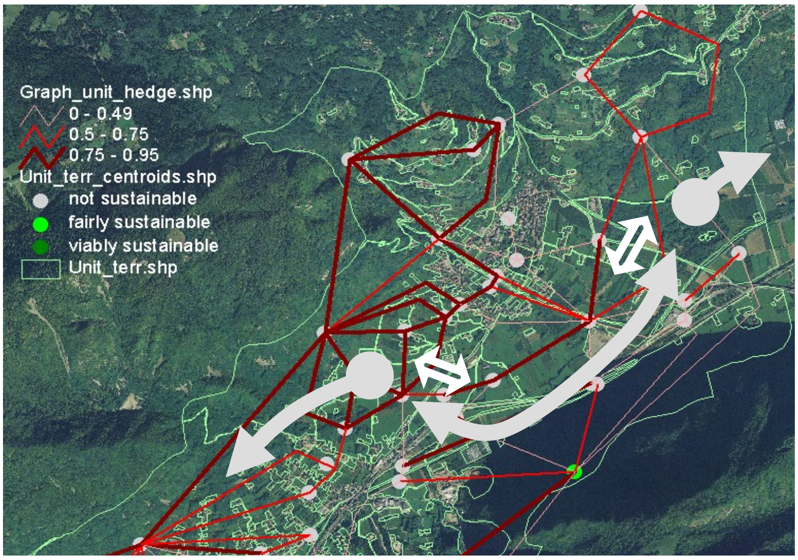


Fig. 6.9 Spatial graph of connectivity for grassland species, on aerial photograph, green arrow indicates the possible dispersal flow along the valley floor; yellow arrow identifies the potential gaps of connectivity.

In addition, another graph was derived from the spatial graph of connectivity, concerning the local connectivity (providing a "local graph" of connectivity). This graph characterizes all the links between adjacent Patches. The structure of local links allowed defining the contribution of each Patch to the local connectivity, in terms of available paths for species dispersal. Thus, it was possible to distinguish value of each Patch within the same Units. This value was defined as "importance of node" likewise for Units (see § 3.3).

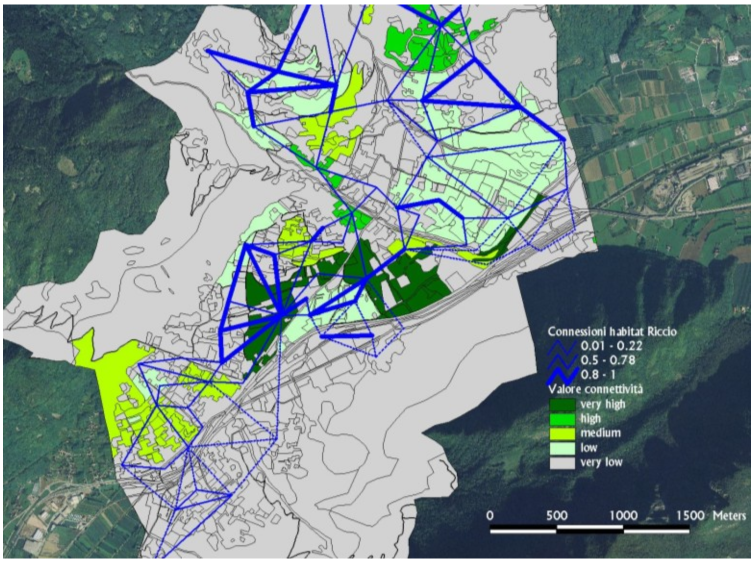


Fig. 6.10 Local graph of connectivity and the value for each Patch related to the relative contribution to the connectivity.

The resulted knowledge framework concerning the ecological characteristics of the Patches helped defining indications for the design phase of Roncegno master plan. In particular, two types of actions were outlined: linear interventions (involving linear elements of landscape) and superficial interventions (concerning superficial elements).

6.3.1. Linear interventions

These actions would involve linear elements of landscape, entailing management of existing linear habitats or creation of new linear habitats (as tree line, hedgerows). These require generally few resources but may provide effective improvement of ecological functioning of the Roncegno territory. Item by item, in order of priority (i.e. lower costs and expected higher effects), indications may be the following.

Maintenance or improvement of existing linear habitats, as hedgerows of native species, thickets and tree lines, between parcels and cultivations. These elements usually sustain even 80% of biodiversity in cultivated areas. Above all, the ecological improvement of thickets related to a temporal water course may enhance habitat potentialfor grassland and wetland species (element 9 in Fig. 6.12). This improvement would consist in maintaining autochthonous plant species.

Creation of new linear habitats, such as hedgerows of native species, thickets, lines of trees, along rural roads. The rural roads of Roncegno, lacking a considerable traffic flow (far less than 500 vehicles per day), does not seem working as effective barrier for species dispersal. For this reason, some habitat functions could be established. This action would consist in increasing the hedgerows density, to which many grassland species are related. The new linear habitats may improve the habitat connectivity also at valley floor scale (green arrow in Fig. 6.9). A priority for this indication could involve linear habitat elements inserted between low density urban areas (element 30 and 31 in Fig. 6.12); these may increase existing habitats nearby residential areas and provide buffer functions.

Restoration of fluvial functioning. The water courses are crucial elements for ecological continuity of a landscape. These within Roncegno territory are completely artificial. An effective intervention, among others, would imply the functional restoration of the "Brenta vecchio" ditch, linking the Larganza stream outlet and the Chiavona stream outlet and to the nature reserve Palude di Roncegno (element 21 in Fig. 6.12). This would increase wetland habitats as well as their connectivity.

6.3.2. Areal interventions

Superficial interventions suppose management or restoration of areal elements of the landscape, such as conversion from one land-use to another or creation of new habitats, in order to improve the ecological functioning or. In particular, for Roncegno, the following indications can be proposed, in order of foreseen effectiveness.

Restoration and creation of new habitats. This indication aims at supporting the viability of amphibian populations (chance of survival in future). Priority intervention would include the Larganza stream outlet (1 in
Fig. 6.13). Actually, this area is heavily disturbed by waste deposit, heavy vehicle traffic due to the nearby construction site, invasive and exotic plant species which are dominating. An

effective intervention may create a small wetland area, linked with the ditch **"**Brenta vecchio", linking also the close natural reserve (SAC).

Maintain and improve the bio permeability of residential areas. This goal could be achieve by planting autochthonous plant species appreciated by wildlife (e.g. feeding shrubs with berry) and by substituting the exotic species as *Robinia pseudoacacia* and *Ailanthus altissimo,* in the remnant vegetated areas (as 7 in
Fig. 6.13), especially in those located between residential areas. This may maintain a fair connectivity inherent the municipality, enabling linkages between habitats at valley floor and those at slopes.

Project details of the planned residential settlement, also, may help maintaining both local habitat connectivity and valley floor continuity with an aware design of pattern and orientation of buildings (as 4 in
Fig. 6.13). A specific suggestion is to place buildings along the axes parallel to the valley floor (which forms a bottleneck in this zone) leaving space for faunal corridors (likewise in Fig. 6.11.

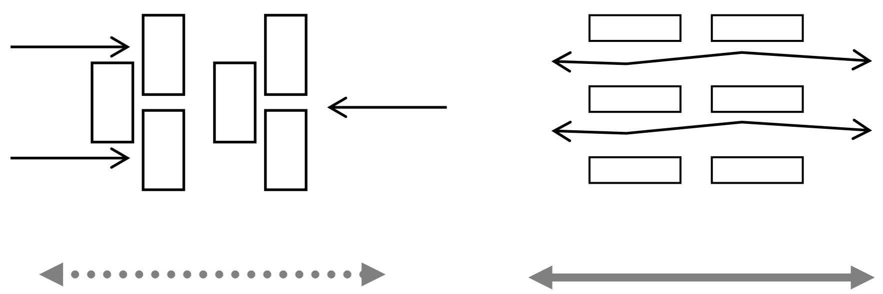


Fig. 6.11 Orientation of buildings and possible dispersal flows.

Fig. 6.12 Suggestions about linear interventions.

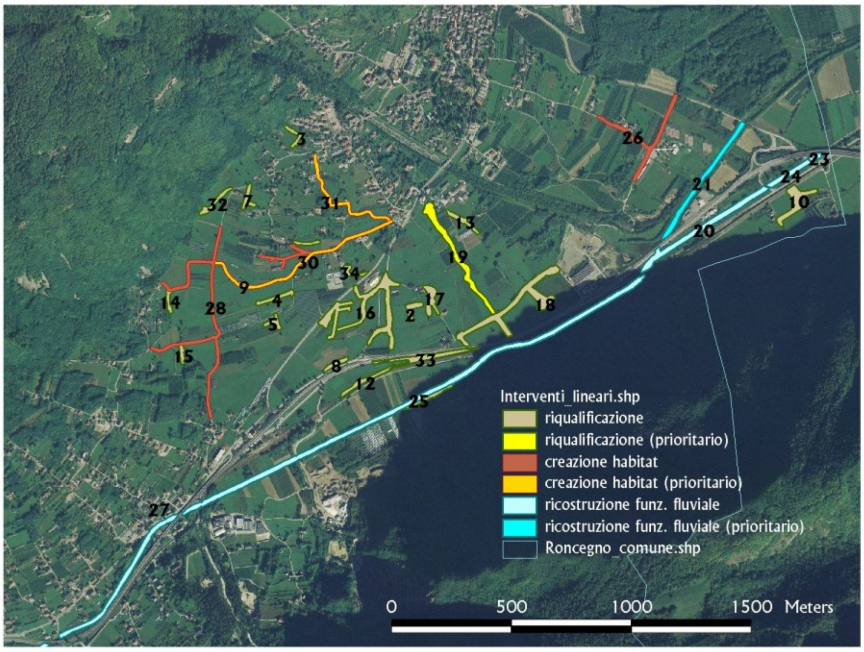
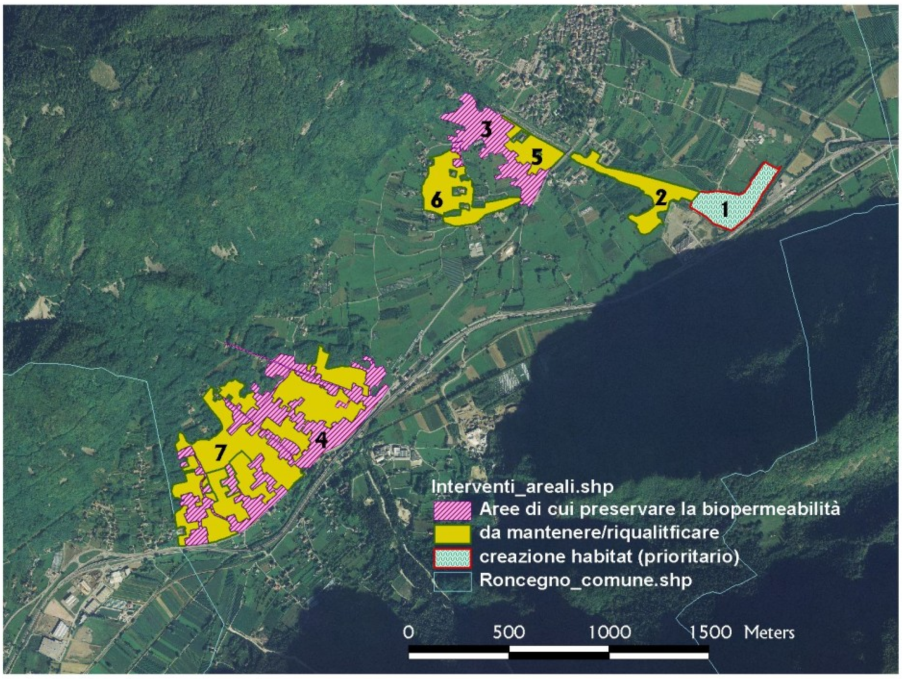


Fig. 6.13 Superficial intervention.



Chapter 7

Summary and conclusions

7.1. Introduction

The land-use and cover changes are the major causes of the biodiversity loss. This is particularly true in the contexts of Alpine valley floor, where increasing human-driven pressures affect remnant habitats and fragile ecosystems. To pursue biodiversity conservation, aiming environmentally sustainable development, spatial planning should maintain landscape ecological functions in order to guarantee the habitats and supporting processes for as many species as possible.
Planners as well as other stakeholders involved in land-use changes need value-based information or at least information easily obtainable that provides clear insights on the ecological consequences of these land-use changes. In other words, this information should support understanding of processes and ecological functions acting in a landscape, and should be based on a limited set of data.
Currently, the assessments of the ecological impact of project or plan proposals have several shortcomings. Spatial planning often disregards the different biodiversity components, just focused on species richness of protected areas. Besides, the copious number of landscape-oriented indices fails especially in providing an understanding of disruptive changes of ecological processes.
A former project, to which I contributed, was meant to provide an assessment of biodiversity assets for the Trento Province (northern Italy) in order to support environmental decision by a decision support system: the Information System of Ecological Value, or *Sistema Informativo della Sensibilità Ambientale* (SISA). This has been provinding to planners value-based information, through a reliable and transparent evaluation, based on expert judgments, but this has some limitations for contexts of the valley floor and concerning ecological processes.
The attempt to solve the above mentioned shortcomings and the SISA project limitations fostered the motivation behind this study. To this end, a methodology for ecological assessment was proposed. The overall objective is to support land-use planning towards development of ecologically sustainable landscapes. In particular the ecological assessment concerns the main processes supporting local biodiversity in human dominated and fragmented landscapes: habitat potentialand functional connectivity. The study has focused on one specific environmental context, i.e. the landscapes of the Alpine valley floor.
A secondary objective of the study was to develop a decision support system easily applicable by environmental agency officers or planners. This means requiring as few data as possible in order to permit reliable evaluation of planning ecological consequences even in

the cases where poor data sets are available. Moreover, the outputs should be easy to understand and to be communicated to all stakeholders involved in planning or assessment process.

These objectives were pursued through the following steps:

- Review the current studies on environmental assessment, within EIA and SEA applications and related research, in order to identify the shortcomings and key-issues that need to be addressed (chapter 2).
- Description of the relevant characteristics of targeted environment. In this study the chosen environment was Alpine valley floor, showing it requires urgent attention regarding biodiversity conservation (chapter 3).
- Development of a methodology for the assessment of landscape ecological functioning, attempting to overcome the literature limitations reported from literature review (chapter 4)
- Application of the proposed methodology on a case study within Alpine valley floor, to test the applicability and usefulness of the proposal (chapter 5 and 6).

The study derived the main theoretical foundation from landscape ecology, the research field dedicated to study of spatial pattern of ecological processes. In particular, the main theoretical references were meta-population and spatial graph theory. The results of these steps have been shaped in a geographical information system, consisting in a geo-database and structured rule sets. This geodatabase represent the studied area in terms of landscape objects with specific qualities depending on the proper attributes and neighbourhood. The rules, defining these attributes, are structured in a multiple level hierarchy, but, finally, were based only on the land-cover and vegetation data. Once a land use changes, by performing the rule sets is possible update all object information.

The proposed methodology constitutes a contribution to current issues of the environmental assessment and spatial planning, although it has limits. The next sections develop this statement and describe some indications for further research.

7.2. Current shortcomings in assessment of land-use impacts on biodiversity

Concepts such as “biodiversity”, “habitat loss”, “habitat fragmentation” and “connectivity” are key concepts for a land use planning aware of possible ecological impacts. Habitat loss and fragmentation are the major threats to biodiversity and the most studied (Lindenmayer and Fischer 2006). In spite of their importance, these concepts are often used in ambiguous manner and not adequately distinguished within environmental assessment and planning applications (Lindenmayer and Fischer 2007; Scolozzi 2008). The biodiversity is often assessed merely as species richness (Noss 1990). Many studies dealing with habitat evaluation refer actually to native vegetation, disregarding the species perspective, i.e.

habitat requirements, home range or in other words the resources and conditions that produce occupancy for species (as in the same SISA project, Diamantini et al. 2007). Especially the ecological processes, involving the functional and structural component of biodiversity, seem to be neglected (e.g. as in Rossi et al. 2008).
Moreover the literature concerning environmental assessment and management, including EIA and SEA applications, seem to be slowly inheriting the recent developments on these key concepts from environmental sciences. In fact, landscape ecology and conservation biology literature is publishing a rapidly increasing number of papers focused on habitat loss and fragmentation issues, as mentioned in Chapter 2. In comparison, the environmental assessment and management literature shows a slow increase in attention on these subjects and only in the last decade. Besides, the biodiversity treatment within EIA applications still reveals serious shortcomings. Important limits are related to ambiguous interpretations (and measurements) of ecological terms, as above mentioned, and to the definition of the values (e.g. "nature value" or "ecological significance"). The last depends on the definition of conservation value for affected environment and on conservation goal. In fact, different motivations for assessing aspects of biodiversity or different interests on biodiversity lead to different value systems. Many ecological evaluations lack transparency on value systems or lack explicited conservation goals.
On the other hand, there are literally hundreds of metrics developed to analyze the landscape structure. Landscape pattern indices have two potentially attractive attributes for planners and designers. They are relatively efficient tools that can be applied quickly to several different alternative plans (as opposed to more complex models that may have prohibitive computing requirements, expensive calibration requirements, or be discipline-centred). Landscape metrics are accessible tools, easily acquired, fully documented and applicable to digital data (e.g. in a GIS). Because of that these indices are often used incorrectly. According to several comparative reviews, many landscape metrics are strongly correlated, thus, they can be confounded. The most of them shares an important shortcoming: they disregard to account for scale-dependent variation in species response to landscape characteristics. Hence, the application of such indices does not allow explicitly referring to ecological processes or to their meaningful changes caused a land-use change. In the words of Gustafson (1998) "applying the many available indices without a priori hypothesizing relationships can result in a fishing expedition", simply looking for the indices that confirm the desired outcome.

7.3. Contribution to the literature shortcomings

The proposed approach starts by acknowledging that patches of habitats are open or constrained by landscape barriers and interact with others throughout habitat networks. The approach pivots on two crucial ecological processes that maintain local biodiversity in human-dominated landscapes, namely habitat potentialand functional connectivity. This is meant to include more components of biodiversity, rather than simple species number. Thus, different ecosystems could have been valued not only by the presence of species, but also by the virtue of processes acting in the landscape and sustaining them.

The assessment of these processes relies on a species-centred approach, based on target species. The approach involves a species perspective for the assessment in terms of ecological profiles, i.e. habitat requirements, home range, dispersal distance, barrier sensitivity. Resorting to the conditions for species occurrence, rather than modelling the presence based in distribution data, allows assessing the functioning of those areas currently without species data.

The selected species are small-size animal, belonging to different groups (i.e. amphibians, insects, birds, small mammals). These species cover a wide range of sensitivity to habitat fragmentation and land-use changes. They perceive local landscape features and small-patch ecosystem as important determinants of inter-patch movement and habitat utilisation. Thus, they supply insights on landscape "quality" properly valid for the scale of decision-making at municipality level.

The assessment framework involves three nested levels, each characterized by its own objects and properties, according to the complexity of hierarchical systems. The quality of each object depends on the quality of nearby objects at the same level and on the quality of upper-level (or lower-level) objects. This enables to evaluate "emergent properties" of a landscape; consequently allows assessing impacts on ecological properties considering non-linear mechanisms. The same land-use change may cause really different impacts depending on the ecological relations between the affected area and its surroundings. This permits to assess cumulative impacts on habitat potentialdue to land-use changes, as shown in the case of master plans' mosaic for study area. The overall habitat loss resulted larger than that resulted by summation of single habitat losses.

The habitat potentialassessment provides qualitative classification related to specific habitat functions rather than habitat suitability in terms of numbers. The numerical values, e.g. in Boitani's models (Boitani et al. 2002), may be difficult to interpret. Some questions may arise, for example: what is the difference between areas with suitability 2 and 3? A 3 graded area can sustain a stable local population? Will an area, valued as 3, of 10 hectares, maintain the same score after loss of 4 hectares? The proposed approach helps to answer these questions, although approximately, supporting a more clear understanding of ecological processes behind.

In detail, the classification approach considers mosaic of vegetation covers (i.e. related patch-clusters) instead of single vegetation cover (i.e. single vegetation-patch) at time. This supports more realistic assessment of habitat values. These mosaics are the likely providers of resources for species, which commonly depend on multiple habitat types including the ecotones, i.e. requiring different vegetation types for different needs (e.g. feeding, nesting). Such vegetation assemblages, often rich in species, are difficult to be considered in common vegetation class-based (seen as “habitat”) evaluation (as example, see again Boitani’s habitat suitability models, 2002). Furthermore, considering vegetation mosaics and disregarding the vegetation naturalness as evaluation criterion supports a sound assessment of threatened cultural landscapes at valley floor, which in Alpine region may support more species than natural potential vegetation covers (i.e. mainly woodland).

The carrying capacity estimation, related to fulfilment of species habitat requirements, provides a quantification of biodiversity assets of a study area, i.e. the number of reproductive units (e.g. species pairs, families or territories) supported, or RU. The same estimation constitutes a reliable quantification of habitat loss within planning scenario. The habitat loss can be defined in terms of reproductive units no more sustained by the affected landscape. This implies an operational impact definition and tangible measure of ecological consequences; these may found references for compensation quantification and help also non-ecologists in defining value of impacts as well as restoration goals. In the example for Roncegno municipality, more attention was given to the most threatened species populations (with higher RU loss).

The connectivity analyses include both structural and functional characteristics, using barrier effect and spatial graph concepts. Besides the distances, the species response to landscape features and finer-scale movement decisions are considered. The approach provides an original application of graph theory on landscape assessment at local scale. Although the spatial ecological relations are only estimated, the resulting knowledge framework enables to differentiate ecological functioning of areas by species-based and topological criteria. The spatial graph of connectivity allows evaluating importance of patches by their contribution to overall connectivity. Moreover, it permits to visualize remnant possible paths for species dispersal in highly fragmented areas. Thus, the spatial-graph based approach allows assessing indirect impacts due to fragmentation. The common practice of focusing on a narrow window of analysis (e.g. using buffer zone surrounding a construction site) hinders the carrying out of adequate prediction of fragmentation impact. Differently, within the present methodology, even relatively distant habitats may appear “affected” by the isolation of a connected habitat, in term of flux of species dispersal (chapter 4 and 5). Thus, it is possible to scan the impacts “spreading” along the habitat networks, since the isolation (or loss) of a habitat-node may affect not only nearby habitats but even the functioning of the whole Unit Network.

The assessment of habitat network functioning constitutes an ecological indicator able to capture a considerable part of ecosystem complexity, representing key information about structure, function and composition of a landscape. In addition, this assessment remains simple enough to be easily understood, promoting the awareness about ecological consequences of land use changes, i.e. a decision-maker will likely have a better understanding about the extinction risk for local population species rather than about an index number (e.g. derived from connectivity indexes).

The qualitative multi-attribute evaluation, proposed at the end of methodology procedure, performs a clear separation between prediction and assessment of impacts, according to guidelines for ecological evaluation in environmental impact assessment. This evaluation is meant to translate species-specific assessments into ecological relevance values. This makes the proposed methodology suitable for EIA applications and consequently may support the same environmental decision targeted by the SISA project.

On the other hand, the ecological value map (Fig. 5.17), resulted from the qualitative evaluation, may appear similar to the final map resulted by the SISA project (§ 2.3). Nevertheless, a significant difference exists between them. The present evaluation model relies on a dynamic, rather than a static, interpretation of ecosystems and living communities, by considering spatial attributes of habitat functioning. Within the present framework, the matrix has significant effects on the species composition and richness within a habitat, affecting the species dispersal, the habitat functions and the spatial ecological relationships among areas. The two approaches can be distinguished, as in Fig. 7.1: the first (a) approach considers several criteria-attributes of environment by means of overlay mapping of different attribute-layers. This implies a "vertical" relation between value maps or criteria-map for the same site. The proposed approach (b) takes into account spatial relations within the same layer (horizontal relations) and between layers (vertical relations). The rule set that depict the spatial dependencies allows modelling a kind of "response" of landscape ecological functions to land-use changes.

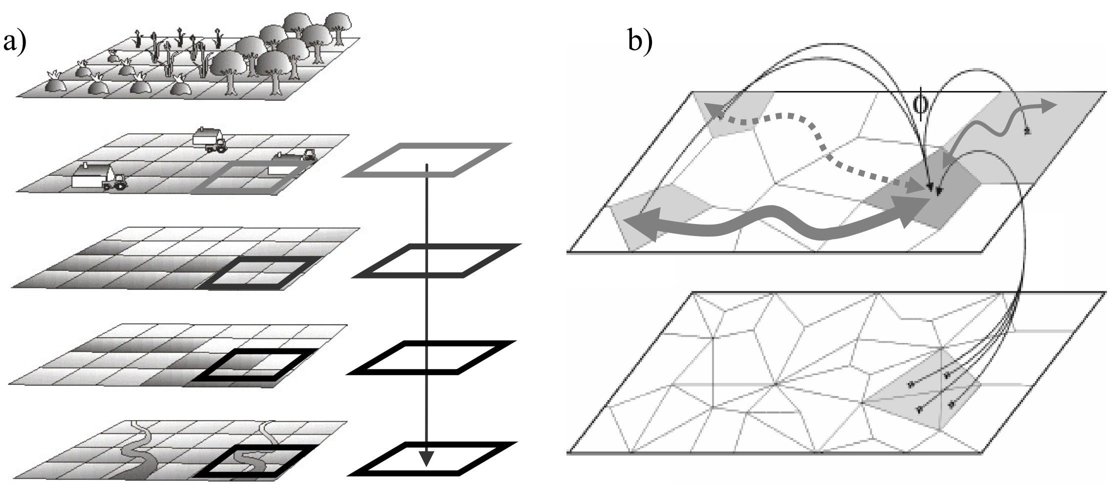


Fig. 7.1. Two approaches used in environmental assessment: "spatial linearity" and "spatial complexity".

7.4. Methodology application and limitations

The proposed approach was tailored for the particular context of study area, an Alpine valley floor, northern Italy. In particular, the selection of target species and the barrier characterization were performed according to the characteristics of the study area. Nevertheless the methodology could be applied in other contexts, carrying out adequate modification (as selecting another species set). It is believed that the approach is of interest to a wider range of contexts and application. Considering an application to other context than the case study and specific scope of this framework, for each step of methodology some indications should be noted. These are reported below, starting from the end, i.e. the ecological value maps, then, to get more detailed information about the specific level of species-based evaluations and, finally, the basic data of EUNIS-based land cover map. Concluding, a general remark on validation and uncertainty is reported.

Ecological evaluation. The result of ecological value maps (§ 6.6) should been seen as introductory analysis within a planning study. The ecological value map represents an initial evaluation based on those habitat considered important in each case study. This requires defining priority among habitat types, in other words, clearly setting conservation goals.

For the case study two priority scenarios were shown (in Fig. 5.16 and Fig. 5.17), but different decision rules (see Annex VI) can be proposed, according to different conservation goals. As example, debated issues are whether to preserve maximum species diversity or to preserve only the valuable species. In any case, one can easily track their influence throughout the whole procedure (the decision tree, in Tab. 4.6), and check the effect on the final results.

Anyhow, the developed evaluation cannot be considered exhaustive for a biodiversity assessment. The approach relies only on the habitat potential for small-size animal species, i.e. the approach concerns the small-ecosystem level of biodiversity.

Habitat potentialassessment. Different habitats were not explicitly valued by virtue of presence of rarest or most endangered species; in spite some guidelines claims that (Bonn et al. 2002). Somehow, referring habitat evaluation (accordingly the conservation efforts) to the rare species would make the results difficult to be validated; because the monitoring needed may become hardly workable. Moreover, since resources for conservation are limited, spending the most money on species with the highest extinction probabilities is not the most efficient way of promoting recovery or minimizing extinction rates (Possingham et al. 2002). The proposed habitat models are a kind of formalization of a priori knowledge about the species (obtained by literature and expert consultation). The knowledge on species should be validated through confrontation with presence data, as some authors have claimed (Lindenmayer et al. 2002b). Anyhow, in human dominated and highly fragmented landscape, performing effective monitoring to calibrate assumptions on habitat potentialmay be unfeasible. Considering the metapopulation dynamics, current suitable habitats may be temporarily unoccupied by expected species and the less suitable patches may lodge temporarily moving individuals. Hence, the proposed habitat assessments, performed on study area (§6.4), could be acknowledged as a plausible tradeoffs providing operational results.

Functional connectivity analyses. The connectivity definition relied on experts' judgment of fictitious situations of barrier effect on few species (see § 6.5). Accordingly, the assessment of network habitat potentialshould be considered within a qualitative framework, not aiming at modelling population dynamics and movements. Many approaches have been developed consisting in dispersal modelling based on radio-telemetry or field tests based on direct observation (e.g. Driezen et al. 2007; Riber 2006). These studies may provide more realistic simulation and assessment of barrier effects.

Anyway, concerning the flux of dispersal, despite its importance, relatively few studies document rates of inter-patch movement and even fewer determine population level consequences of these movements. This deficiency limits our ability to understand the dynamics of spatially structured populations and apply that knowledge to conservation efforts (Bowne and Bowers 2004). For example a disruption of landscape connectivity may not result in the immediate extinction of a species. Nevertheless, the latter could set the stage for delayed extinctions that occur years or decades later (i.e. extinction debt, Hanski and Ovaskainen 2002; Tilman et al. 1994).

The expert-based assessment of barrier effect is a further shortcut that can be justified by the study objective concerning information easily obtainable. Nevertheless, the results showing likely impacts on local target species populations may be policy relevant. At least, these can form early warnings on land use consequences, provide suggestions for local policy change, and also point out directions for possible further analyses.

The target species. The selected species were meant to represent local biodiversity at the Alpine valley floor, by the assumption that the habitat requirements are nested, and in particular the selected species cover most of habitats in the study area. The effectiveness of focal species as surrogates of wider communities, i.e. being representative for biodiversity, should be confirmed by monitoring and field surveys. Anyhow, the methods to confirm that effectiveness are not unique and still debated in literature, besides some ecologists criticise the "nested" property. Probably, ideal surrogates do not exist. Thus, the selected species and related assumptions were meant to be a feasible shortcut, fulfilling the mentioned study objective. Biodiversity surrogates reduce the amount of time and data required when compared to the collection of detailed multi-species inventory data.

However, the choice of small size animal species as target for habitat potentialassessment may involve undervaluing or overvaluing of current habitat potentials, especially for the small ecosystems or habitats. As example for amphibians, it was not possible to record all possible breeding sites within water bodies, which can be sufficient for carrying out the life cycle, similarly it would be rather unfeasible noting the disturbance of tourism and related activities locally affecting the habitats.

Sources of uncertainty. A general remark for the presented methodology is the lack of consideration for the uncertainty factors that affect both the data used and the evaluations applied. In particular, two kinds ("natures") of uncertainty (Walker et al. 2003) can be recognized within this study. One is the uncertainty due to the imperfection of our knowledge, which may be reduced by more research and empirical efforts ("epistemic uncertainty"). This mainly characterizes the knowledge about the species, their ecological traits and their responses to land-use changes. A lot of studies, within the biology of conservation and the landscape ecology have been developed aiming at understanding and modelling these issues. Anyhow, this research was meant using current knowledge in planning practice rather than contributing in the field of ecology.

The other uncertainty, strictly related to the above cited, is due to inherent variability of ecological processes that is of ecosystem complexity ("variability uncertainty"). The same aspects cited above are inherently unpredictable. For example, the validation of habitat models is complicated by the time span of ecological processes, thus even the outcome of models may not be validated in a short time perspective. Similarly, the effectiveness validation of surrogate species requires long-term monitoring. Concluding, the precautionary principles should be pursued. The indications provided by this study should be seen as hypotheses open for testing, best applied in comparative assessment, as within EIAs. They may be applied in adaptive strategies, whereby management prescriptions are applied as experiments to test the hypotheses (Lindenmayer et al. 2000a).

7.5. Directions for further research

The proposed approach can be extended in more directions. In geographical sense, the application may concern other alpine areas, with a minimum modification, or other environments by re-calibrating the assessment steps within the same framework (e.g. reviewing the target species set). Concerning the overall scope, the approach can include the supporting the ecological compensation (Pileri 2007) or the biodiversity tradeoffs (Van Teeffelen et al. 2008). Besides, the landscape ecological model that ground the whole assessment methodology could be extended towards object orientation (Blaha and Premerlani 1997).

Towards supporting ecological compensation and habitat restoration. The results of methodology application may assign a clear responsibility to decision makers or planners: they will have to justify or compensate a loss of species reproductive units due to a plan. This may involve the opportunity to design impact mitigation and to find an operational reference for ecological compensation. Compensation measures willl be aimed at maintaining the size and quality of ecological networks as a response to development (Ten

Kate et al. 2004). Besides, legal foundations exist for habitat compensation, this generally state that the quality and connectivity of the ecosystem network should be maintained (“No Nett Loss” principle EC 2007). In a compensation study, the proposed ecological evaluation would also allow distinguishing the sites which are areas expected to be easily restored o improved in terms of habitat functioning. The amount of area required to be restored (habitat restoration) would be related to the number of reproductive units no more supported in the planning scenario (habitat loss). In this sense, the focal-species based approach provides coarse quantitative indication for habitat restoration. By formulating the problem with a clear objective and an economic constraint could help finding efficient solutions to the problem. Recently, this issue was focused by the EcoTRADE project (http://www.ecotrade.ufz.de). The presented case study may contribute to that project suggesting the graph-oriented approach for modelling the dynamic habitat network.

Object-oriented approach. The probability that a focal species is present in a site (Patch) depends on the other vegetated sites in the landscapes. These dependencies are based on hierarchical properties of a complex system, as considered in the present methodology. The Patches, defined as a vector polygon, are entities likewise “objects” (as interpreted in terms of object-oriented programming language, Brown et al. 2005): discrete entities that have location, some level of spatial extension and attributes (here related to ecological processes). Polygon-Patches likewise “objects”, have identity, attributes and behaviour defined through rule sets (“methods” in programming terms), all encapsulated within the geodatabase (structured using PostGIS-Postgresql). In particular, the geodatabase perfoms hierarchically nested entity definitions that inherit data attributes from higher levels. Since object orientation can be described as a strategy for organising a system as a collection of interacting objects that can combine data and behaviour (Blaha & Premerlani, 1998), the presented study could form a introductory application of object-oriented landscape model (Wu and David 2002) to ecological impact assessment at local scale. This may permit to gain more comprehensive understanding or relationships between “landscape objects”, landscape ecological values and land-use changes.

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ANNEX I - Land cover according to EUNIS classes

Tab. 1 Level 3 Habitats cover statistics (the original class denominations are shortened).

Level 3 Habitats		Sum (ha)	Average (ha)	Count	Max	Min
Permanent mesotrophic lakes, ponds ()	C1.2	635,21	90,74	7	358,02	0,12
Permanent eutrophic lakes, ponds ()	C1.3	0,39	0,19	2	0,27	0,12
Springs, spring brooks and geysers	C2.1	2,47	1,24	2	1,32	1,16
() fast, turbulent watercourses	C2.2	34,35	0,54	64	3,15	0,01
Temporary running waters	C2.5	2,98	0,60	5	1,52	0,10
Species-rich helophyte beds	C3.1	2,39	0,22	11	1,11	0,01
Water-fringing reedbeds ()	C3.2	2,23	0,45	5	1,01	0,08
Water-fringing beds of tall canes	C3.3	2,72	0,27	10	0,88	0,06
() shores with pioneer () vegetation	C3.5	17,68	0,47	38	2,45	0,02
() sparsely vegetated shores ()	C3.6	28,86	1,20	24	5,24	0,02
Unvegetated () shores ()	C3.7	4,81	0,80	6	1,74	0,32
Transition mires and quaking bogs	D2.3	0,95	0,47	2	0,61	0,34
() pastures and aftermath-grazed meadows	E2.1	1,34	1,34	1	1,34	1,34
Low and medium altitude hay meadows	E2.2	565,19	1,28	441	13,56	0,01
Mountain hay meadows	E2.3	56,18	1,48	38	6,87	0,06
() fertilised grassland, sports fields ()	E2.6	203,47	1,96	104	13,88	0,02
Unmanaged mesic grassland	E2.7	1,96	0,49	4	0,79	0,19
Mediterranean tall humid grassland	E3.1	8,73	0,67	13	2,95	0,02
Moist or wet () grassland	E3.4	7,40	0,74	10	2,13	0,03
Anthropogenic herb stands	E5.1	67,42	0,72	94	32,39	0,01
Thermophile woodland fringes	E5.2	21,34	0,61	35	2,89	0,06
Moist or wet tall-herb and fern fringes ()	E5.4	15,28	0,41	37	1,59	0,04
Sub-continental parkland	E7.2	2,57	0,51	5	0,95	0,03
Temperate thickets and scrub	F3.1	0,82	0,82	1	0,82	0,82
Riverine scrub	F9.1	29,61	0,64	46	8,75	0,02
Willow carr and fen scrub	F9.2	2,55	0,23	11	0,57	0,03
Species-rich hedgerows of native species	FA.3	2,64	0,29	9	0,78	0,04
Species-poor hedgerows of native species	FA.4	7,23	0,14	53	0,66	0,01
Vineyards	FB.4	85,08	0,98	87	9,69	0,01
Riparian and gallery woodland ()	G1.1	74,45	1,46	51	19,29	0,02
Mediterranean riparian woodland	G1.3	10,02	1,43	7	4,02	0,17
Fagus woodland	G1.6	107,05	8,23	13	33,63	0,01
Thermophilous deciduous woodland	G1.7	1912,82	13,19	145	169,00	0,01
Fruit and nut tree orchards	G1.D	939,98	2,86	329	53,20	0,05
Abies and Picea woodland	G3.1	279,93	14,73	19	108,02	0,48
Pinus sylvestris woodland	G3.4	134,84	7,93	17	37,98	0,13
Mixed Abies - Picea - Fagus woodland	G4.6	604,49	16,34	37	97,84	0,01
Mixed deciduous and coniferous woodland	G4.8	1321,40	15,02	88	108,44	0,01
Mixed Pinus () Quercus woodland	G4.C	201,35	14,38	14	42,61	0,01
Mixed forestry plantations	G4.F	1,99	1,99	1	1,99	1,99
Lines of trees	G5.1	13,13	0,25	52	5,17	0,01
Small broadleaved deciduous () woodlands	G5.2	215,68	0,74	291	11,75	0,01
Small coniferous anthropogenic woodlands	G5.4	0,53	0,27	2	0,32	0,21
Small () Anthropogenic woodlands	G5.5	5,63	0,94	6	1,36	0,63
Early-stage () woodlands and regrowth	G5.6	57,86	0,56	103	3,39	0,01
Coppice and early-stage plantations	G5.7	2,95	0,37	8	0,75	0,06
Recently felled areas	G5.8	20,86	0,65	32	5,75	0,02
Screes	H2	27,44	1,44	19	5,63	0,05

Inland cliffs, rock pavements and outcrops	H3	73,39	3,34	22	20,93	0,01
Mixed crops () and horticulture	I1.2	851,41	1,85	460	28,32	0,01
Arable land with unmixed crops ()	I1.3	331,83	2,00	166	38,69	0,01
Bare tilled, () abandoned arable land	I1.5	15,42	0,51	30	1,42	0,10
Large-scale ornamental garden areas	I2.1	36,02	2,57	14	11,15	0,17
() ornamental and domestic garden areas	I2.2	48,63	1,03	47	6,86	0,05
Residential buildings of () town centres	J1.1	36,06	18,03	2	32,54	3,52
Residential buildings () urban peripheries	J1.2	317,65	4,24	75	40,91	0,01
Urban and suburban public buildings	J1.3	14,01	2,00	7	3,79	0,59
Urban () industrial and commercial sites ()	J1.4	73,22	5,63	13	28,36	0,30
() construction and demolition sites	J1.6	3,07	1,53	2	2,60	0,47
Scattered residential buildings	J2.1	484,68	0,47	1021	15,96	0,01
Rural public buildings	J2.2	27,66	1,32	21	5,96	0,09
Rural industrial and commercial sites ()	J2.3	51,82	1,30	40	7,10	0,15
Agricultural constructions	J2.4	92,12	0,58	160	8,13	0,04
Disused rural constructions	J2.6	0,22	0,11	2	0,13	0,09
Rural construction and demolition sites	J2.7	12,29	0,82	15	4,98	0,12
() quarries	J3.2	26,11	1,86	14	7,73	0,04
Recently abandoned () industrial sites	J3.3	21,00	4,20	5	17,05	0,15
Road networks	J4.2	254,61	0,61	414	6,96	0,01
Rail networks	J4.3	28,66	0,87	33	4,47	<0,01
Pavements and recreation areas	J4.6	17,02	1,06	16	6,02	0,05
Constructed parts of cemeteries	J4.7	1,69	0,56	3	0,92	0,33
Highly artificial non-saline running waters	J5.4	2,50	0,31	8	1,13	0,03
Waste () from building () demolition	J6.1	7,68	0,85	9	2,94	0,16
Agricultural and horticultural waste	J6.4	1,88	0,47	4	1,09	0,11

ANNEX II - The indicator species

<u>Hazel Dormouse - *Muscardinus avellanarius*</u>

Habitat

The dormouse is a small mammal (up to 40g bodyweight) with specialized habitat requirements, consequent upon an arboreal life, feeding on tree flowers and fruits. The dormouse is a specialist feeder (Bright and Morris 1994) and thrives best in diverse, low growing woodland, especially hazel (Corylus avellana) coppice 10-20 years old (Bright and Morris 1990). A high diversity of deciduous shrubs and tree species is essential to provide, in combination, a sequence guaranteeing food availability throughout the seasons (Berg and Berg 1998).

Home range, natural density and distribution

Mean home ranges (Minimum Convex Polygon) are 0.45 ha for males and 0.19 ha for females. They rarely travel more than 100 m from their daytime nest (mean maximum distance in coppice with standards woodland, 55.4 m, Bright et al. 1994).

In 'good' areas, the population density appears low (5-10 per hectare, Berg & Berg, 1990) in comparison with that for other woodland small mammals (up to hundreds per hectare). It is likely that small populations are often particularly vulnerable to stochastic events and consequently vulnerable to extinction of local populations (Bright and Morris 1996). In the woods smaller than 20 hectares, even if suitable, there is a markedly lower incidence of dormice, probably because low population density means that such woods are too small to support a minimum viable population, estimated as 100 UR.

In the past it was much more common in rural contexts rich in hedgerows. In Trento Province it is still quite common (Locatelli and Paolucci 1998), present in 23 biotopes over 41 valley floor biotopes.

Related species. Several species may have beneficial from the presence of Hazel dormouse, e.g.: predators as Red Fox *Vulpes vulpes*, Badger *Meles meles* and raptors of the Strigidae group (Typical owls)

Nuthatch - *Sitta europaea*

Habitat

The nuthatch is a small (23 g), insectivorous, cavity-nesting woodland bird. It is predominantly sedentary and nests in natural holes in large trees of mature broadleaved woodlands or in holes previously used by woodpeckers (Picidae). For this reason it is sensitive to forest isolation, fragmentation and forest structure degradation (Bani et al., 2006). In particular the fragmentation seems to inhibit its movements between territories and thus induces functional isolation of patches (Matthysen 1999). Due to its strict forest dependence, the nuthatch has been assessed as forest fragmentation indicator species in a number of studies in Central and Northern Europe (e.g. Bellamy et al. 1998; Langevelde 1999; Verboom et al. 2001b), or as focal species in nature reserve selection (e.g. Bani, 2006 #270)(Lorenzetti and Battisti 2007). These studies have generally shown the negative effects of forest fragmentation on nuthatches, including the scarce presence of breeding in small woods (<10 ha), lower abundance in small woods than in continuous forestand the limitation of highly fragmented landscapes for supporting viable populations without external immigration. Anyway the species was shown to use the hedgerows and small woodland for its movements through the landscape (Verboom et al., 1991)

Home range, natural density and distribution

They live in territories of 1–3 ha that they maintain in pairs throughout the year for feeding and breeding (González-Varo et al. 2008). Only young birds disperse and dispersal distances range from 1 km in continuous forest to more than 3 km in highly fragmented landscapes (<2% of forest cover)(Langevelde 1999; Matthysen and Schmidt 1987). The daily distance for Nuthatch can range from 250-800 m (van Rooij et al. 2003). In this study 1500 m are used to assess habitat potential at Unit level.

The minimum required area for a key-population is 40 ha (Verboom et al., 2001), for stepping stone function at least 5 ha (Pouwels, 2008, personal communication).

In Trento province the nuthatch population is quite stable but at low density, its presence is limited by meaningful reduction of nesting sites e.g. coppice woodland management (Pedrini et al. 2005). The population total size is estimated from 1000 and 10000 pairs, with higher occurrence under 1000 m of altitude (Pedrini et al. 2005).

Related species. Several species may have beneficial from suitable habitat for Nuthatch"most of other forest birds" (van Langevelde et al. 2002) Woodpeckers (Picidae group, Bogliani, 2007, personal communication).

<u>Hedgehog - *Erinacaeus europaeus*</u>

Habitat

The hedgehog is medium size (800-1200 g), mammal, its body length ranges from 135 to 265 mm. It is nocturnal omnivorous, eats a wide range of invertebrates, preferring earthworms but also eats frogs, small reptiles, young birds, young mice, small bird eggs, acorns and berries. The preferred foraging habitat is open pasture in rural habitat and mown grass playing fields, golf courses and gardens in urban areas (Doncaster 1994) but they nest and spend the major part of the day mainly in deciduous forest (Riber 2006). In an Italian study, the most frequented environments are the pastures and the embankments of the canals, followed by the bush and the dry meadows and while agricultural land appeared to be rarely frequented (Boitani & Reggiani, 1983). The hedgehog is the prey of badger (Meles meles) and they are potential competitors for the same invertebrate prey particularly earthworms (Lombricus terrestris) and beetles. The local variations in the abundance of hedgehogs are related to the distribution of a principal predator (badger) and a major food resource (Micol, 1994). Hedgehogs are also frequently reported as traffic victims. Huijser and Bergers (Huijser and Bergers 2000) estimated that between 113,000 and 340,000 hedgehogs may fall victim to traffic in The Netherlands each year.

Home range, natural density and distribution

The size of the areas frequented by the hedgehogs varied greatly, ranging from 0.8 ha to 4.6 ha in Campbel's study (1973, in Boitani & Reggiani, 1983), from 5.5 ha to 102.5 ha in Boitani & Reggiani's (1983), the usual home ranges of hedgehogs of generally less than 40 ha (Doncaster et al., 2001) an average male hedgehog's home range is calculated in 12 ha (Morris, 1991). Usually there is simultaneous presence of more than one animal without manifesting any territorial defence reactions. Empirical studies had shown that hedgehogs are capable of travelling distances of up to 3.8 km from a release point and up to 9.9 km in total, but natural dispersals between populations up to 4 km apart are rare, compared to an average home range span of 0·8 km (Doncaster et al. 2001).

The population density is esteemed to be 8/ha by Campbell (1973) or 2/ha by Parkes in New Zeland (1975, in Boitani & Reggiani, 1983), 1.79/ha (without badger activity) by Micol et al. in UK (1994), in small scale agricultural landscapes of The Netherlands one would expect to find a density of 30 hedgehogs per 100 ha (Huijser, 1999; Huijser & Bergers, 2000). In Trento Province it is quite common, present in 29 biotopes over 41 valley floor biotopes.

Related species. Many species may have beneficial from suitable habitat for hedgehogs, such as its predator: Common Buzzard *Buteo buteo*, Eagle Owl *Bubo bubo* (Marchesi et al, 2002; Sergio et al, 2003), Badger *Meles meles*, (Duncaster, 1992) and Red Fox *Vulpes vulpes*, other species ecologically related are the same reported for red-backed shrike.

Red-backed shrike - *Lanius collurio*

Habitat

The Red-backed shrike is a migratory passerine that over-winters in southern and eastern Africa and breeds across most of Europe. It occupies a variety of half-open habitat, with scrubland, bushes for nesting and breeding (Boitani et al., 2002), it requires a rich insect fauna to feed upon (Hagemeijer et al., 1997). An Italian study, in Apennines, have shown that its favoured habitats is pasture/cultivation mosaics (Pedrini et al., 2005) flanked by or interspersed with shrubs/hedges (15–20% of the surface of the 1-ha medium-sized territory) (Brambilla et al. 2007), in fact the abundance of Red-backed Shrikes depends on shrub cover and grazed areas (Laiolo et al. 2004 for Italian Alps; Vanhinsbergh & Evans 2002 for Austrian Alps). The species is a typical species of moderate farming systems that has shown a serious decline in most of Europe (Hagemeijer et al., 1997) disappeared almost completely from large areas (Tucker & Evans 1997), e.g. extinct as regular breeding bird in Britain (Tucker & Heath, 1994), following the increasing intensification and mechanization of traditional agriculture, which led to intensive farming with abundant pesticide use, increased nitrogen input and loss of marginal features, such as hedgerows (Husting & Bekhuis, 1993). For these reasons the red-backed shrike is chosen as indicator species in conservation project, e.g.: as bioindicator species in Polish farmland (Tackàcs et al., 2004; Gołanski & Gołanska, 2008), as target animal species for the implementation of the Pan European Ecological Network (Ozinga & Schaminée, 2005), as focal species in analysis and development of ecological networks (Van Rooij et al., 2003; Van der Sluis et al., 2003).

Home range, natural density and distribution

The densities may reach more than 5000 breeding pairs/50 km^2 in Northern Italy (Van der Sluis et al., 2003). In Trento province it is estimated a number of about 1000 breeding pairs, (Pedrini et a., 2005), the observed territories are mainly under 1000 m of altitude, with a observed density of 1 pair / 3-4 ha (Pedrini, personal communication).

Related species. Many species may have beneficial from suitable habitat for red-backed shrike, such as: Blackcap *Sylvia atricapilla*, Goldfinch *Carduelis carduelis*, Spotted Flycatcher *Muscicapa striata*, Whinchat *Saxicola rubetra* (Falcucci et al. 2007), *Licenidae* and *Satiridae* Butterfly groups, Hare *Lepus europaeus* (Bogliani, 2007, personal communication)and the related predator as Common Scops Owl *Otus scops*, Common

Kestrel *Falco tinnunculus* (Falcucci et al. 2007), Eagle Owl *Bubo bubo* (Marchesi et al, 2002).

Ediblefrog - *Rana synklepton esculenta* (complex)

Habitat

The Ediblefrog Rana esculenta complex (named also “green” or “water frog”) is a hybrid genetic associate between R. lessonae and R. rudibunda, the commonest species frog in Italy (Francesco Ficetola & De Bernardi, 2004), but also included by Habitat Directive (CEE 92/43) as “species that could become object of management measures”. According to the red list of endangered amphibian species in Trentino (Pedrini et al., 2005), is a threatened species, by human-induced and natural habitat alteration and pollution (from pesticides increasingly used in agriculture). This is due mainly to his site fidelity, shown by more than one empirical study (e.g. 88% of individuals monitored between years did not move from their capture pond, in Holenweg & Reyer 2001) and his low mobility.

The Ediblefrog are more dependent on water than other anurans, needing water for breeding but also in other seasons, otherwise they are a very adaptable species and may colonize very heterogeneous habitats. They do not require large terrestrial habitat and can live also in polluted water (Bucci et al., 2000; Pavignano et al., 1990; Ficetola & Scali, 2002). They prefer permanent shallow water bodies, with sunny riverside and shores rich in vegetation (Ficetola and De Bernardi 2004a), because the Ediblefrog have a quick development and they survive well in temporary wetlands. The occurrence of Ediblefrog, likewise for other anurans, depends mainly on the isolation of the ponds and it is hindered by fish presence (Ficetola and De Bernardi 2004a) .

Home range, natural density and distribution

They are able to disperse through artificial drainage ditches (as frogs move independently of the current in relatively slow running water). But these features provide no habitat functions (Mazerolle, 2004). The Ediblefrog can cross over long distances using water bodies: the maximum dispersal distance recorded ranges from 1200 m (Sjogren, 1976) or 1760 m (Holenweg, 2001) to 15000 m (Tunner, 1992). But the migration rate decreased with increasing distance between ponds already within some 100 m (Sjögren, 1991; Sjögren and Gulve, 1994 in Holenweg, 2001) with a mean distance of 150 m, measured in a Swiss valley floor (Holenweg Peter, 2001). This is according with the species sensitivity to landscape composition for the Ediblefrog: the landscape within a circle of 100-300 m radius around the pond best explains pond occupancy (in Lombardy, Northern Italy, Ficetola & De Bernardi, 2004).

The density can widely range from 100 to 1000 RU per hectare. In Trento province…

Related species. A landscape able to sustain the Ediblefrog may support the presence of the other 12 amphibians, present in Trentino, such as: Salamandra salamandra, Triturus alpestris, Triturus carnifex, Triturus vulgaris, Hyla intermedia, Rana dalmatina, Rana ridibunda, Bombina variegata, Bufo viridis, Bufo bufo, that were often observed with Rana esculenta. (Servizio Parchi e Conservazione della Natura 2003)

Other species may have beneficial from suitable habitat for Ediblefrog: many species of inverterbrate (as, generally, Odonata insect group), small mammals related to fresh water ecosystem (as *Neomys anomalus*, *Crocidura suaveolens*), aquatic birds (as *Acrocephalus palustris*) and of course the frog predator as the species of *Ardeidae* family (herons), *Strigidae* family (owls) and the Water Snake (*Natrix* genus).

Damselfly - *Calopteryx virgo*

Habitat

The Damselfly *Calopteryx virgo* is included within Odonata group (Zygoptera family). Populations of many odonate species have been declining in temperate regions, due to habitat loss and management, threatened by drainage, pollution and removal of vegetation, such as aquatic macrophytes (Hofmann & Mason, 2004). It must also be considered that the suitability of the adjacent terrestrial landscape, important in the life cycle of many Odonata, is also highly influenced by human activity. The group has attracted more and more attention in recent decades and has been used as a source of indicator species by several authors (see a review in Sahlen & Ekestubbe, 2001). The genus Calopteryx in particular is tolerant of high flow velocities, commonly encountered at upstream sites (larval habitat), otherwise on rivers of moderate flow with stony and gravely beds, but also it can be found along wooded streams (Nelson et al, 2000). Its preferred habitats are narrow channel, high steep banks with overhanging vegetation, shaded by limited cover of mainly marginal aquatic vegetation, between arable farming and pastures and secondarily ponds (Hofmann & Mason, 2005).

Home range, natural density and distribution

No specific studies providing information on Damselfly as minimum home range and natural density was found during the carrying out of present research. The used values were obtained by suggestion of experts, as representative of the genus rather than the single species. In Trento Province, the species is quite rare and declining, currently recorded in 5 biotopes over 41 valley floor biotopes.

Related species. The species may have beneficial from damselfly habitat are generally the same reported for Ediblefrog.

ANNEX III
Sets of classification rules for the six target species

We report the original names of the third level EUNIS categories, in some cases we only report the code for the second level (e,g. E1 instead of E1.1) or the first level (e.g. J instead of J1, or J1.1) meaning all the relative sub-categories are included.

Classification rules for *Rana synlklepton esculenta*

Edible Frog	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area >1 ha AND: (Permanent mesotrophic/eutrophic lakes, ponds and pools (C1.2/3) AND <150 m off shore) OR Springs, brooks (C2.1) OR Permanent non-tidal, smooth-flowing watercourses (C2.3) OR Temporary running waters (C2.5) OR Species-rich helophyte bed (C3.1) OR Water-fringing reedbeds and tall helophytes other than canes (C3.2) OR Water-fringing beds of tall canes (C3.3) OR Periodically inundated shores with pioneer and ephemeral vegetation (C3.5) OR Transition mires and quaking bogs (D2.3) OR Seasonally wet and wet grasslands (E3.1/3/4/5, E5.4) OR Riverine and fen scrubs (F9.1)	≥ 100 (100-1000)	At least one breeding area > 3 ha OR breeding and survival patches mosaic within the distance of 300 m AND total area > 5 ha	≥ 500
Survival	Covers AS ABOVE but area <1 e > 0.1 ha OTHERWISE area > 0.5 ha AND Permanent non-tidal, turbulent watercourses* (C2.2) OR *Salix* carr and fen scrub (F9.2) OR Riparian and floodplain gallery woodland, with *Alnus, Betula, Populus* or *Salix* (G1.1/2/3) (* only if with water-fringing vegetation otherwise set Dispersal)	≥ 10	breeding or survival patches mosaic within the distance of 300 m AND total area > 1 ha (including the case of one Breeding/Survival Patch >1 ha)	≥ 100
Dispersal	Covers for Breeding habitat class but area <0.1 ha OR Covers for Survival habitat class but area <0.5 ha OTHERWISE Unvegetated or sparsely vegetated shores with soft or mobile sediments (C3.6) OR Unvegetated OR sparsely vegetated shores with non-mobile substrates (C3.7) Semi-open grassland (mesic, dry) (E1, E2) OR Woodland fringes and clearings and tall forb stands (E5.1/2) OR Sparsely wooded grasslands with trees/bushes (30-50%) (E7.2, F3.1) OR Gardens and allotments with trees/bushes, hedgerows (FA.3/4 OR Shrub plantations (FB.4) OR Deciduous forest (G1.6/7/B/D, G5.1/2/4/5/6/7/8) OR Mixed coniferous and deciduous forest (G4.6/8/C/F) OR Early-stage natural and semi-natural woodlands (G5.6) OR mature coniferus forest (G3.1/4/7/F) OR Mixed crops of market gardens and horticultures (I1.2) OR intensive unmixed cultivated land (arable land, allotment	Likely some individuals	Breeding/survival/dispersal cover > 60% of the Unit	Likely some RU

	without trees/bushes) (I1.1/3/5) OR Ornamental and domestic garden areas (I2.1/2)			
Unsuitable	Sparsely developed land without trees/bushes OR Recently felled areas (G5.8) OR Bedrock (with scattered pine, semi-open, open), unvegetated OR sparsely vegetated habitats (H2/3) OR open water > 150 m off shoreline OR Agricultural constructions (structures connected with agriculture OR horticulture (including greenhouses) (J2.2) OR Highly artificial nonsaline running waters (J5.4)			
Hostile	Developed land with no OR sparse vegetation (0-30%) OR constructed, industrial and other artificial habitats (J)			

Classification rules for *Calopteryx virgo*

Damselfly	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area >0.5 ha AND (Permanent mesotrophic/eutrophic lakes, ponds and pools (C1.2/3) AND <150m off shoreline) OR Springs, brooks (C2.1) OR Permanent non-tidal, smooth-flowing watercourses (C2.3) OR Temporary running waters (C2.5) OR Species-rich helophyte bed (C3.1) OR Water-fringing reedbeds and tall helophytes other than canes (C3.2) OR Water-fringing beds of tall canes (C3.3) OR Species-poor beds of low-growing water fringing OR amphibious vegetation (C3.4) OR Periodically inundated shores with pioneer and ephemeral vegetation (C3.5) OR Transition mires and quaking bogs (D2.3) OR Seasonally wet and wet grasslands (E3.1/3/4/5, E5.4) OR Riverine and fen scrubs (F9.1/2)	≥ 100	At least one breeding patch > 3 ha OR breeding and survival patches mosaic within the distance of 500 m, with total area > 5 ha	≥ 300
Survival	Covers AS ABOVE BUT area >0.05 ha AND area <0.5 ha OTHERWISE area ≥ 0.5 ha AND Permanent non-tidal, fast, turbulent watercourses* (C2.2) OR Unvegetated or sparsely vegetated shores (C3.6) OR Unvegetated or sparsely vegetated shores with non-mobile substrates (C3.7) OR Sedge and reedbeds, normally without free-standing water (D5) OR Riparian and floodplain gallery woodland, with *Alnus, Betula, Populus* or *Salix* (G1.1/2/3) (*only if with water-fringing vegetation otherwise set Dispersal)	≥ 10 (10-100)	breeding and survival patches mosaic > 1 ha within the distance of 500 m (including the case of one Breeding/Survival Patch >1 ha)	≥ 100
Dispersal	Covers AS for Breeding Class BUT area <0.05 ha OR Covers AS for Survival Breeding Class BUT area <0.5 ha OTHERWISE Semi-open grassland (mesic, dry) (E1, E2) OR Woodland fringes and clearings and	Likely some RU	total area of breeding/survival/dispersal patches cover > 60%	Likely some RU

	tall forb stands (E5.1/2) OR Sparsely wooded grasslands with trees/bushes (30-50%) (E7.2, F3.1) Gardens and allotments with trees/bushes, hedgerows (FA.3/4 OR Shrub plantations (FB.4) Deciduous forest (G1.6/7/B/D) OR Early-stage natural and semi-natural woodlands (G5.1/2/4/5/6/7/8) OR Mixed coniferous and deciduous forest (G4.5/6/8/B/F) OR Mixed crops of market gardens and horticultures (I1.2) OR intensive unmixed cultivated land (arable land, allotment without trees/bushes) I1.1/3/5 OR Ornamental and domestic garden areas (I2.1/2) OR			
Unsuitable	Sparsely developed land without trees/bushes OR mature coniferous forest (moist, mesic) (G3.1/4/7/F) OR Bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats H2/3 OR open water > 150 m off shoreline OR Agricultural constructions (structures connected with agriculture or horticulture (including greenhouses) J2.2 OR Highly artificial non saline running waters J5.4			
Hostile	Developed land with no or sparse vegetation (0-30%), constructed, industrial and other artificial habitats (J)			

Classification rules for *Lanius collurio*

Shrike	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area ≥ 10 ha AND Sparsely wooded grasslands with trees/bushes (E5.2/4*, E7.2*) OR open grassland (mesic, dry) (E2.2/3/7*, I1.5*) OR Moist grassland, seasonally wet and wet grasslands (E3.1/3/4/5*) OR Hedgerows (FA.3/4**) OR Small deciduous woods (G5.1/2/4/5/6/7/8*) * with thorny shrubs (>5%) **with density 2.5 km/km^2 or width > 15 m[a]	≥ 3	at least one Breeding patch mosaic >40 ha OR mosaic of Breeding and survival patches within < 500 m with a total area > 40 ha	≥ 12
Survival	Covers AS ABOVE BUT Area <10 ha and >3 ha OTHERWISE Area ≥ 3 ha AND Temperate and mediterranean-montane scrub (F3.1) OR arable land with low intensity agricultural methods I1.3 OR Mixed crops of market gardens and horticulture (I1.2)	≥ 1	Breeding and/or survival patches mosaic within 500 m, with total area >10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 3
Dispersal	Covers AS ABOVE BUT Area <3 ha, OTHERWISE Agriculturally-improved, re-seeded and heavily fertilised grassland, including sports fields and grass lawns (E2.6) OR Anthropogenic herb stands (E5.1) OR Shrub plantations (fruit, vineyards) (FB.4, G1.D) OR Deciduous forest (G1.1/2/3/6/7/B) OR Mixed coniferous and	Unlikely some individuals	Dispersal/survival/breeding patches cover >60% of total area	Likely some individuals

	deciduous forest (G4.5/6/8/B/F) OR Intensive unmixed crops (I1.1) OR Riverine and fen scrubs (F91/2) OR poor fens and transition mires (D2.3) OR - Littoral zone of inland surface waterbodies (C3.1/2/3/4/5/6/7) OR Anthropogenic herb stands (E5.1) OR Cultivated areas of gardens and parks (I2.1/2) OR Agricultural and horticultural waste (J6.4)* (possible feeding source)			
Unsuitable	Surface standing waters (C1.2/3) OR mature coniferous forest (moist, mesic) (G3.1/4/7/F OR bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats (H2/3) OR Surface running or standing waters (C2.1/2/3/5) OR Low density buildings, Scattered residential and rural buildings (J2.1/2/3/4/6/7) OR Pavements and recreation areas (J4.6) OR Highly artificial man-made waters (J5.4) OR Waste deposits (J6.1)		Otherwise	
Hostile	Buildings of cities, towns and villages (J1) OR Extractive industrial sites (J3) OR Transport networks (J4)			

Classification rules for *Erinacaeus europaeus*

Hedgehog	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area ≥ 5 ha AND Sparsely wooded grasslands with trees/bushes, hedgerows (E7.2, F3.1, FA.3/4) AND Open grassland (mesic, dry) (E2.2/3/6) OR Woodland fringes (E5.2/4) OR Mixed crops of market gardens and horticulture (I1.2) OR Abandoned arable land (I1.5) OR Cultivated areas of gardens and parks (I2.1/2) OR Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7/8)	≥ 3	At least Breeding patch mosaic > 40 ha OR mosaic of survival and breeding patches within the distance of 1500 m with a total area >40 ha	≥ 28
Survival	Classes AS ABOVE BUT Area <5 ha and >2 ha OTHERWISE Area ≥ 2 ha AND Anthropogenic herb stands (E5.1) OR Fruit and nut tree orchards (G1.D) OR Moist grassland, seasonally wet and wet grasslands (E3.1/3/4/5) OR Cemetery (J2.2)	≥ 1	Survival and/or breeding patches mosaic within < 1500 m with a total area > 10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 7
Dispersal	Classes AS ABOVE BUT Area <2 ha OTHERWISE Mixed coniferous and deciduous forest (G4.5/6/8/B/F) OR - Deciduous forest (G1.1/2/3/6/7/B) OR Base-rich fens and calcareous spring mires (D2.3) OR Intensive unmixed crops (I1.1-3) OR Scattered residential and rural buildings (J2.1/2/6) OR Agricultural constructions (J2.4) OR Shrub plantations (fruit, vineyards) (FB.4) OR Littoral zone of inland surface water bodies (C3.1/2/3/4/5/6/7) OR Riverine and fen scrubs (F9.1/2) OR mature	Likely some individuals	Dispersal/survival/breeding patches cover >60% of total area	Likely some RU

	coniferous forest (moist, mesic) (G3.1/4/7/F)			
Unsuitable	Bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats (H) OR Surface running or standing waters (C1.1/3,C2.1/2/3/5, D2.2) OR Pavements and recreation areas (J4.6) OR Highly artificial man-made waters (J5.4) OR Waste deposits (J6.1/4)		Otherwise	
Hostile	Buildings of cities, towns and villages (J1.1/2/3/4/6) OR Rural industrial and commercial sites (J2.3-4-5-7)Extractive industrial sites (J3.2/3) OR Transport networks (J4.1/2)			

Classification rules for *Sitta europaea*

<u>**Nuthatch**</u>	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area ≥ 5 ha AND Mature coniferous forest (G3.1/4/7/F*) OR Mature mixed coniferous and deciduous forest (G4 G4.5/6/8/B/F*) OR Mature deciduous forest (G1. 1/2/3/6/7/B*) *with suitably sized trees: big oaks > 35 cm diameter at breast height otherwise deciduous trees (beech, elm, aspen, ash, birch) with >25 cm or mixed forest with conifers (trees >35 cm) with trunks and/or with hazel, chestnut	≥ 8	At least one breeding patch >40 ha OR survival and/or breeding patches mosaic (considering also patches outside the unit) within < 1500 m with a total area > 40 ha	≥ 40
Survival	Covers AS ABOVE BUT Area <5 ha and >2 ha or OTHERWISE Area ≥ 2 ha AND Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7/8*) OR Coniferous forest (G3*) OR Mixed coniferous and deciduous forest (G4*) OR Deciduous forest (G1*) *with some suitably sized trees (>30 cm including conifers)[a]	≥ 2	Breeding and/or survival patches mosaic within < 1500 m with a total area > 10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 8
Dispersal	Covers AS ABOVE BUT Area <2 ha OR AS ABOVE BUT without suitable sized trees OTHERWISE Hedgerows (FA.3/4) OR Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7/8) OR Fruit and nut tree orchards (G1.D) OR Sparsely wooded grasslands with trees/bushes (E7.2, F3.1) OR Cultivated areas of gardens and parks (I2.1/2) OR Woodland fringes and clearings and tall forb stands (E5.1/2/4) OR Riverine and fen scrubs F9.1/2 OR Shrub plantations (fruit, vineyards) (FB.4)	Unlikely	Dispersal/survival/breeding patches cover >60% of total area	Likely some individuals
Unsuitable	Bedrock, unvegetated or sparsely vegetated habitats (H2,H3) OR Open grassland (mesic, dry) (E2.2/3/6/7, E3.1/3/4/5) OR Littoral zone of inland surface waterbodies (C3.1/2/3/4/5/6/7) OR Mixed crops of market gardens and horticulture (I1.2-3) OR Intensive unmixed crops (I1.1/5) OR		Otherwise	

	Surface running or standing waters (C1.1/3,C2.1/2/3/5, D2.2) OR Buildings of cities, towns and villages (J1.1/2/3/4/6) OR Rural industrial and commercial sites (J2.3-4-5-7) OR Pavements and recreation areas (J4.6) OR Highly artificial man-made waters (J5.4) OR Waste deposits J6.1/4			
Hostile	Extractive industrial sites J3.2/3 OR transport networks J4.1/2/3			

Classification rules for *Muscardinus avellanarius*

<u>Dormouse</u>	***Patch Habitat suitability***	***Habitat potential (RU)***	***Unit Habitat suitability***	***Habitat potential (RU)***
Breeding	Area ≥ 5 ha AND deciduous forest (G1. 1/2/3/6/7/B*) OR coppice, overgrown hedgerows (G5.1/2/4/5/6/7*, FA.3/4*) *with oaks, elms and beech and/or hazel, that maintain a thick layer of scrub plants and underbrush	≥ 20	At least one breeding patch >20 ha OR Survival and breeding patches mosaic within < 150 m with a total area > 20 ha	≥ 100
Survival	Classes AS ABOVE BUT Area <5 ha and >2 ha OTHERWISE Area ≥ 2 ha AND Coniferous forest (G3*) OR mixed coniferous and deciduous forest (G4*) OR deciduous forest (G1*) OR Hedgerows (FA*) OR Lines of trees, small anthropogenic woodlands (G5.1/2/4/5/6/7*) *some suitably sized trees (>30 cm)	≥ 4	survival and/or breeding patches mosaic within < 150 m with a total area > 10 ha (including the case of one Breeding/Survival Patch >10 ha)	≥ 50
Dispersal	Classes AS ABOVE BUT Area <2 ha OR AS ABOVE BUT without suitable sized trees OTHERWISE Thermophile woodland fringes (E5.2) OR Sparsely wooded grasslands with trees/bushes (10-30%) (E7.2, F3.1) OR Temperate thickets and scrub (F5.1) OR Riverine and fen scrubs (F9)	Likely some individuals	Dispersal/survival/breeding patches cover >60% of total area	Likely some individuals
Unsuitable	Inland surface waters (C1-2) OR Transition mires and quaking bogs (D2.3) OR Seasonally wet, wet, mesic grassland, meadow (E2, E3, E5.1-3-4-5) OR Cultivated areas of gardens and parks (I2.1/2) OR Shrub plantations (fruit, vineyards) (FB.4) OR Fruit and nut tree orchards (G1.D) OR Open grassland (mesic, dry) (E1, E2, I1.5) OR Moist grassland, seasonally wet and wet grasslands (E3) OR Littoral zone of inland surface waterbodies (C3) OR Arable land and market gardens (I1) OR Bedrock (with scattered pine, semi-open, open), unvegetated or sparsely vegetated habitats (H)		other cases	
Hostile	Constructed, industrial and other artificial habitats (J)			

ANNEX IV – Correlation between Habitat potentials

Tab.IV.1 Contingency tables of habitat categories defined at Patch level for the three terrestrial target species (as output by SPSS).

		EdibleFrog Patch Habitat					Hedgehog Patch Habitat				
		b	d	h	s	u	b	d	h	s	u
		Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
Hedgehog	b	4	687	0	6	0	697	0	0	0	0
	d	45	1626	504	142	53	0	2370	0	0	0
	h	0	0	623	0	0	0	0	623	0	0
	s	3	459	0	9	6	0	0	0	477	0
	u	10	21	704	50	53	0	0	0	0	838
Dormouse	b	0	164	0	18	0	39	136	0	7	0
	d	0	621	0	71	4	215	375	0	106	0
	h	0	0	1831	0	33	0	519	623	6	716
	s	0	159	0	6	33	17	168	0	13	0
	u	62	1849	0	112	42	426	1172	0	345	122

		Ediblefrog	Hedgehog
Hedgehog	Chi-square	3183,812	.
	df	16	.
	Sig.	<<,000(*)	.(a)
Dormouse	Chi-square	5195,508	2970,343
	df	16	16
	Sig.	,000(*)	,000(*)

Pearson Chi-Square Tests
Results are based on non empty rows and columns in each innermost subtable.
* The Chi-square statistic is significant at the 0.05 level.
a The Chi-square test is not performed for this subtable because row and column variables are identical.

Tab.IV.2 Contingency tables of habitat categories defined at Unit level for the three terrestrial target species pairs (as output by SPSS).

		EdibleFrog Unit Habitat					Hedgehog Unit Habitat			
			b	d	s	u		b	d	s
		Count	Count	Count	Count	Count	Count	Count	Count	Count
Dormouse		2054	116	94	13	13	2290	0	0	0
	b	8	493	322	87	0	0	0	272	638
	d	6	395	307	84	58	0	0	711	139
	s	0	84	0	0	0	0	58	26	0
	u	5	360	506	0	0	0	27	704	140
Hedgehog		2054	116	94	13	13	2290	0	0	0
	b	0	65	20	0	0	0	85	0	0
	d	15	768	882	48	0	0	0	1713	0
	s	4	499	233	123	58	0	0	0	917

		Ediblefrog	Hedgehog
Hedgehog	Chi-square	4640,804	.
	df	12	.
	Sig.	,000(*)	.(a)
Dormouse	Chi-square	4692,642	8756,914
	df	16	12
	Sig.	,000(*)	,000(*)

Pearson Chi-Square Tests
Results are based on non empty rows and columns in each innermost subtable.
* The Chi-square statistic is significant at the 0.05 level.
a The Chi-square test is not performed for this subtable because row and column variables are identical.

Tab. IV.3 Contingency tables between qualitative evaluation results concerning Unit level, Patch level of aggregation and Patch habitat potentialaggregated for the three terrestrial target species pairs (as output by SPSS).

		Patch habitat potential				Unit Habitat value			
		b	d	s	u		fv	n	vv
		Count	Count	Count	Count	Count	Count	Count	Count
Unit Habitat value		3	773	14	1264	2054	0	0	0
	fv	225	374	163	22	0	784	0	0
	n	82	240	117	26	0	0	465	0
	vv	469	728	442	63	0	0	0	1702
Patch Habitat value		3	773	14	0	790	0	0	0
	f_valuable	82	0	163	0	0	163	82	0
	negligible	0	240	0	1375	1264	22	266	63
	p_valuable	0	1102	117	0	0	374	117	728
	v_valuable	694	0	442	0	0	225	0	911

		Patch Habitat Functioning	Unit Habitat Value
Unit Habitat Value	Chi-square	2533,025	.
	df	9	.
	Sig.	,000(*)	.(a)
Patch Habitat Value	Chi-square	8373,409	5363,759
	df	12	12
	Sig.	,000(*)	,000(*)

Pearson Chi-Square Tests
Results are based on non empty rows and columns in each innermost subtable.
* The Chi-square statistic is significant at the 0.05 level.
a The Chi-square test is not performed for this subtable because row and column

ANNEX V - Decision rules for "ecological value" definition

Tab. V.1 Decision rules for Patch Habitat value for Wetland species, using a "maximum" rule, same rules were applied for Grassland Patch and Woodland Patch.

	Pool frog Patch	Damselfly Patch	Wetland Patch
1	***Breeding***	***Breeding***	***Breeding***
2	***Breeding***	***Survival***	***Breeding***
3	***Breeding***	Dispersal	***Breeding***
4	***Breeding***	**Unsuitable**	***Breeding***
5	***Breeding***	**Hostile**	***Breeding***
6	***Survival***	***Breeding***	***Breeding***
7	***Survival***	***Survival***	***Survival***
8	***Survival***	Dispersal	***Survival***
9	***Survival***	**Unsuitable**	***Survival***
10	***Survival***	**Hostile**	***Survival***
11	Dispersal	***Breeding***	***Breeding***
12	Dispersal	***Survival***	***Survival***
13	Dispersal	Dispersal	Dispersal
14	Dispersal	**Unsuitable**	Dispersal
15	Dispersal	**Hostile**	Dispersal
16	**Unsuitable**	***Breeding***	***Breeding***
17	**Unsuitable**	***Survival***	***Survival***
18	**Unsuitable**	Dispersal	Dispersal
19	**Unsuitable**	**Unsuitable**	**Unsuitable**
20	**Unsuitable**	**Hostile**	**Unsuitable**
21	**Hostile**	***Breeding***	***Breeding***
22	**Hostile**	***Survival***	***Survival***
23	**Hostile**	Dispersal	Dispersal
24	**Hostile**	**Unsuitable**	**Unsuitable**
25	**Hostile**	**Hostile**	**Hostile**

Tab. V.2 Decision rules for Unit Habitat value for Wetland species, using a "maximum" rule, same rules were applied for Grassland Unit and Woodland Unit.

	Pool frog Unit	Damselfly Unit	Wetland Unit
1	***Breeding***	***Breeding***	***Breeding***
2	***Breeding***	***Survival***	***Breeding***
3	***Breeding***	Dispersal	***Breeding***
4	***Breeding***	**Unsuitable**	***Breeding***
5	***Survival***	***Breeding***	***Breeding***
6	***Survival***	***Survival***	***Survival***
7	***Survival***	Dispersal	***Survival***
8	***Survival***	**Unsuitable**	***Survival***
9	Dispersal	***Breeding***	***Breeding***
10	Dispersal	***Survival***	***Survival***
11	Dispersal	Dispersal	Dispersal
12	Dispersal	**Unsuitable**	Dispersal
13	**Unsuitable**	***Breeding***	***Breeding***
14	**Unsuitable**	***Survival***	***Survival***
15	**Unsuitable**	Dispersal	Dispersal
16	**Unsuitable**	**Unsuitable**	**Unsuitable**

Tab. V.3 Decision rules (in compact form) for "generic" Patch Habitat value, disregarding the Habitat type, for the scenario in which which Grassland and Woodland habitat types have more importance.

	Wetland Patch	Grassland Patch	Woodland Patch	Patch habitat value
1	***Breeding***	*	*	***High***
2	*	***Breeding***	*	***High***
3	***Survival***	>=***Survival***	*	***Medium***
4	>=***Survival***	***Survival***	*	***Medium***
5	>=***Survival***	>=***Survival***	***Breeding***	***Medium***
6	Dispersal	>=Dispersal	>=***Survival***	Low
7	>=Dispersal	Dispersal	>=***Survival***	Low
8	>=Dispersal	>=Dispersal	***Survival***	Low
9	>=**Unsuitable**	**Unsuitable**	>=Dispersal	**Negligible**

Tab. IV.4 Decision rules for "generic" Unit Habitat value, disregarding the Habitat type, for the scenario in which all the habitat types have the same importance.

Decision rules

	Wetland Unit	Grassland Unit	Woodland Unit	Unit habitat value
1	Breeding	Breeding	Breeding	High
2	Breeding	Breeding	Survival	High
3	Breeding	Breeding	Dispersal	High
4	Breeding	Breeding	Unsuitable	High
5	Breeding	Survival	Breeding	High
6	Breeding	Survival	Survival	High
7	Breeding	Survival	Dispersal	High
8	Breeding	Survival	Unsuitable	High
9	Breeding	Dispersal	Breeding	High
10	Breeding	Dispersal	Survival	High
11	Breeding	Dispersal	Dispersal	High
12	Breeding	Dispersal	Unsuitable	High
13	Breeding	Unsuitable	Breeding	High
14	Breeding	Unsuitable	Survival	High
15	Breeding	Unsuitable	Dispersal	High
16	Breeding	Unsuitable	Unsuitable	High
17	Survival	Breeding	Breeding	High
18	Survival	Breeding	Survival	High
19	Survival	Breeding	Dispersal	High
20	Survival	Breeding	Unsuitable	High
21	Survival	Survival	Breeding	High
22	Survival	Survival	Survival	Medium
23	Survival	Survival	Dispersal	Medium
24	Survival	Survival	Unsuitable	Medium
25	Survival	Dispersal	Breeding	High
26	Survival	Dispersal	Survival	Medium
27	Survival	Dispersal	Dispersal	Medium
28	Survival	Dispersal	Unsuitable	Medium
29	Survival	Unsuitable	Breeding	High
30	Survival	Unsuitable	Survival	Medium
31	Survival	Unsuitable	Dispersal	Medium
32	Survival	Unsuitable	Unsuitable	Medium
33	Dispersal	Breeding	Breeding	High
34	Dispersal	Breeding	Survival	High
35	Dispersal	Breeding	Dispersal	High
36	Dispersal	Breeding	Unsuitable	High
37	Dispersal	Survival	Breeding	High
38	Dispersal	Survival	Survival	Medium
39	Dispersal	Survival	Dispersal	Medium
40	Dispersal	Survival	Unsuitable	Medium
41	Dispersal	Dispersal	Breeding	High
42	Dispersal	Dispersal	Survival	Medium
43	Dispersal	Dispersal	Dispersal	Low
44	Dispersal	Dispersal	Unsuitable	Low
45	Dispersal	Unsuitable	Breeding	High
46	Dispersal	Unsuitable	Survival	Medium
47	Dispersal	Unsuitable	Dispersal	Low
48	Dispersal	Unsuitable	Unsuitable	Low
49	Unsuitable	Breeding	Breeding	High
50	Unsuitable	Breeding	Survival	High
51	Unsuitable	Breeding	Dispersal	High
52	Unsuitable	Breeding	Unsuitable	High
53	Unsuitable	Survival	Breeding	High
54	Unsuitable	Survival	Survival	Medium
55	Unsuitable	Survival	Dispersal	Medium
56	Unsuitable	Survival	Unsuitable	Medium
57	Unsuitable	Dispersal	Breeding	High
58	Unsuitable	Dispersal	Survival	Medium
59	Unsuitable	Dispersal	Dispersal	Low
60	Unsuitable	Dispersal	Unsuitable	Low
61	Unsuitable	Unsuitable	Breeding	High
62	Unsuitable	Unsuitable	Survival	Medium
63	Unsuitable	Unsuitable	Dispersal	Low
64	Unsuitable	Unsuitable	Unsuitable	Negligible

Tab. IV.5 Decision rules for "generic" Unit Habitat value, disregarding the Habitat type, for the scenario in which Grassland and Woodland habitat types have more importance.

Decision rules

	Wetland Unit	Grassland Unit	Woodland Unit	Unit Habitat val
1	Breeding	Breeding	Breeding	High
2	Breeding	Breeding	Survival	High
3	Breeding	Breeding	Dispersal	High
4	Breeding	Breeding	Unsuitable	High
5	Breeding	Survival	Breeding	High
6	Breeding	Survival	Survival	High
7	Breeding	Survival	Dispersal	High
8	Breeding	Survival	Unsuitable	High
9	Breeding	Dispersal	Breeding	High
10	Breeding	Dispersal	Survival	High
11	Breeding	Dispersal	Dispersal	High
12	Breeding	Dispersal	Unsuitable	High
13	Breeding	Unsuitable	Breeding	High
14	Breeding	Unsuitable	Survival	High
15	Breeding	Unsuitable	Dispersal	High
16	Breeding	Unsuitable	Unsuitable	High
17	Survival	Breeding	Breeding	High
18	Survival	Breeding	Survival	High
19	Survival	Breeding	Dispersal	High
20	Survival	Breeding	Unsuitable	High
21	Survival	Survival	Breeding	Medium
22	Survival	Survival	Survival	Medium
23	Survival	Survival	Dispersal	Medium
24	Survival	Survival	Unsuitable	Medium
25	Survival	Dispersal	Breeding	Medium
26	Survival	Dispersal	Survival	Medium
27	Survival	Dispersal	Dispersal	Medium
28	Survival	Dispersal	Unsuitable	Medium
29	Survival	Unsuitable	Breeding	Medium
30	Survival	Unsuitable	Survival	Medium
31	Survival	Unsuitable	Dispersal	Medium
32	Survival	Unsuitable	Unsuitable	Medium
33	Dispersal	Breeding	Breeding	High
34	Dispersal	Breeding	Survival	High
35	Dispersal	Breeding	Dispersal	High
36	Dispersal	Breeding	Unsuitable	High
37	Dispersal	Survival	Breeding	Medium
38	Dispersal	Survival	Survival	Medium
39	Dispersal	Survival	Dispersal	Medium
40	Dispersal	Survival	Unsuitable	Medium
41	Dispersal	Dispersal	Breeding	Medium
42	Dispersal	Dispersal	Survival	Low
43	Dispersal	Dispersal	Dispersal	Low
44	Dispersal	Dispersal	Unsuitable	Low
45	Dispersal	Unsuitable	Breeding	Medium
46	Dispersal	Unsuitable	Survival	Low
47	Dispersal	Unsuitable	Dispersal	Low
48	Dispersal	Unsuitable	Unsuitable	Low
49	Unsuitable	Breeding	Breeding	High
50	Unsuitable	Breeding	Survival	High
51	Unsuitable	Breeding	Dispersal	High
52	Unsuitable	Breeding	Unsuitable	High
53	Unsuitable	Survival	Breeding	High
54	Unsuitable	Survival	Survival	Medium
55	Unsuitable	Survival	Dispersal	Medium
56	Unsuitable	Survival	Unsuitable	Medium
57	Unsuitable	Dispersal	Breeding	Medium
58	Unsuitable	Dispersal	Survival	Low
59	Unsuitable	Dispersal	Dispersal	Low
60	Unsuitable	Dispersal	Unsuitable	Low
61	Unsuitable	Unsuitable	Breeding	Medium
62	Unsuitable	Unsuitable	Survival	Low
63	Unsuitable	Unsuitable	Dispersal	Negligible
64	Unsuitable	Unsuitable	Unsuitable	Negligible