Lifelines for Ramat Hanadiv

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An analysis of the necessity for ecological corridors

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Abstract

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This report presents the results of an analysis of the ecological network for Ramat Hanadiv. We used the LARCH Landscape ecological model to assess, first, the long-term viability of the wildlife populations of Ramat Hanadiv, and secondly, to identify where the most important landscape connections or corridors are situated. Analysis shows that almost no species are viable in Ramat Hanadiv alone; almost all require some exchange with surrounding populations. The exchange with surrounding areas is therefore essential for biodiversity in Ramat Hanadiv. Specific de-fragmentation measures are important. The best measure to improve viability is to ensure that a corridor eastward is maintained. The best location for the corridor is most likely through the industrial zone. A potential corridor through the Taninim River would be another option. This would likely require further study and a significantly larger investment of resources.

Keywords: ecological network, Israel, landscape connectivity, corridors, LARCH analysis, spatial ecology.

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Summary

Biological diversity is highly dependent on the quality, quantity, and spatial cohesion of natural areas. Fragmentation of natural habitats severely affects the abundance of species. A solution to this problem is the development of ecological networks, linking core areas of nature by means of corridors and small habitat patches. This report presents the results of an analysis of the ecological network for Ramat Hanadiv. We used the LARCH Landscape ecological model to assess, first, the long-term viability of the wildlife populations of Ramat Hanadiv, and secondly, to identify where the most important landscape connections or corridors are situated.

For this purpose, we have selected the following species which are indicative of Ramat Hanadiv, and may be affected by fragmentation; six mammal species, one bird species, one reptile, and one butterfly species. For these species, ecological information was collected and parameters required for modelling such as habitat preference, home range, and dispersal distance were derived where possible from existing Israeli literature. In some cases data from other areas or from the LARCH database was used. Parameters were adjusted for the local conditions based on expert input.

A land cover map was prepared in GIS based on a land-use map. This map combined with the vegetation map for Ramat Hanadiv, a forest cover map, and remote sensing data for the wider region, is considered of sufficient quality for species modelling.

Of the nine species initially selected, seven species provide meaningful results on the landscape scale, for these habitats. Analysis shows, that only three species are viable in Ramat Hanadiv alone and that almost all require some exchange with surrounding populations. The exchange with surrounding areas is therefore essential for biodiversity in Ramat Hanadiv. In particular, the large mammal species, Roe deer and Mountain gazelle, are vulnerable to fragmentation and are likely to disappear in the long term. However, almost all species will decrease as a result of the scenario of industrial development.

Specific defragmentation measures are important for Roe deer and Mountain gazelle, but will benefit all other species as well. The best measure to improve viability will be to ensure that corridors eastward are maintained as these are the true 'lifelines' for Ramat Hanadiv. The best location for the corridor would be northeast of Ramat Hanadiv, through the industrial zone. Another possible corridor exists in regional plans along the Taninim River, but this possibility has not been studied in detail. This corridor would require further analysis and likely significantly more resources would be required considering the length of the corridor and the current land-use (a much wider corridor would be necessary if the length were to increase). As such, this possibility has not been assessed in this study. The width of the planned corridor (50 m) is insufficient for the important species as the corridor should be at least 100-150 metres wide. Also, the corridor requires that a safe and functional crossing of the main road is developed. This should still be addressed in greater detail.

Additional recommendations for Ramat Hanadiv include involvement of stakeholders in the planning process, development of the quarry, and specific measures to develop a 'green business site'. Stakeholders are an essential part of a harmonised development plan. The quarry south of Ramat Hanadiv can add crucial habitat, which can also support wetlands in the region. A green business site can support the environmental goals of Ramat Hanadiv.

תקציר (Hebrew Summary)

המגוון הביולוגי תלוי במידה רבה באיכות, בכמות וברציפות המרחבית של אזורים טבעיים. קיטוע בתי גידול טבעיים משפיע במידה ניכרת על עושר בעלי החיים ושכיחותם במרחב. פתרון לבעיה זו הוא פיתוח של רשתות אקולוגיות (ecological networks), המחברות אזורי ליבה טבעיים באמצעות מסדרונות וכתמים קטנים של בתי גידול דומים. דו"ח זה מציג את תוצאות ניתוח הרשת האקולוגית הסובבת את רמת הנדיב. בניתוח נעשה שימוש במודל האקולוגי-נופי LARCH במטרה לאמוד את חיוניות אוכלוסיות חיות הבר ברמת הנדיב לטווח הארוך ולזהות מיקומים אופטימאליים למסדרונות האקולוגיים או מעברי בעלי-החיים החשובים ביותר בין רמת הנדיב לסביבתה, אשר יתמכו באופן מיטבי בחיוניות אוכלוסיות חיות הבר.

למטרה זו נבחרו תשעה מינים, אופייניים לרמת הנדיב וכאלה העלולים להיפגע עקב קיטוע, ביניהם שישה מיני יונקים ומין אחד מכל אחת מהקבוצות: עופות, זוחלים ופרפרים. על כל אחד ממינים אלה נאסף מידע אקולוגי על בסיס ספרות קיימת וחוות דעת מומחים, והוגדרו פרמטרים בסיסיים הדרושים להרצת המודל: העדפות בית הגידול, תחום המחייה ומרחק ההפצה. במקרים של מידע חסר נעשה שימוש בנתונים מאזורים אחרים או מבסיס הנתונים של LARCH. הפרמטרים הותאמו לתנאים המקומיים על סמך חוות דעת של מומחים מישראל.

מפת תכסית הוכנה באמצעות מערכת מידע גיאוגרפי (GIS), תוך התבססות על מפת שימושי קרקע (של מפ"י). מפה זו, בשילוב עם מפת מבנה הצומח של רמת הנדיב, שכבת תמ"א 22 ליער וייעור ונתוני חישה מרחוק מהסקאלה האזורית (תרשים 5), מאפשרת יצירת מודל באיכות מספקת עבור תשעת מיני המבחן.

עבור שבעה מתוך תשעת המינים שנבחרו הראה המודל תוצאות מובהקות: ניתוח הנתונים מצא כי שלושה מינים בלבד יצליחו להתקיים ברמת הנדיב לאורך זמן תחת תרחיש של קיטוע נופי, וכי **כמעט כל המינים זקוקים לקשר פיזי עם אוכלוסיות במרחב הסובב את רמת הנדיב על מנת לשמור על חיוניות אוכלוסיותיהם. היונקים הגדולים - אייל הכרמל והצבי הארץ ישראלי, צפויים להיפגע באופן הקשה ביותר בתרחיש של קיטוע נופי, והמודל חוזה כי ייעלמו בטווח הארוך.** שאר האוכלוסיות צפויות ברובן להדלדל תחת תרחיש שבו פיתוח אזורי התעשייה ממזרח לרמת הנדיב ייצור בידול כמעט מוחלט מהסביבה.

לאור תחזית זו, **ישנה חשיבות עליונה לנקיטת צעדים ספציפיים למניעת קיטוע לצורך המשך קיום אוכלוסיות אייל הכרמל והצבי הארץ ישראלי, אך הם יהיו מועילים גם ליתר המינים.** האמצעי הטוב ביותר לשיפור קיום המינים הוא להבטיח שמירה על מעברי בעלי חיים (מסדרונות אקולוגיים) מזרחה לרמת הנדיב, שכן אלה הם עורקי חיים אמיתיים לאוכלוסיות חיות הבר בפארק הטבע. המיקום הטוב ביותר למסדרון כזה הוא צפונית-מזרחית לרמת הנדיב, דרך אזור התעשייה המתוכנן. מסדרון

פוטנציאלי נוסף קיים בתוכניות אזוריות (תממ 5/6) לאורך נחל תנינים, אך אפשרות זו לא נחקרה בפרוטרוט. מסדרון זה יחייב ביצוע ניתוח נוסף והשקעה ניכרת, בהתחשב באורכו של מסדרון זה ובשימוש הקרקע הנוכחי (מסדרון ארוך יותר יצריך את הרחבתו בהתאמה). במחקר זה לא התבצעה הערכה מפורטת של חלופה זו.

רוחבו של המסדרון המתוכנן בפרויקט התעשייה והמגורים של זיכרון יעקב "פארק היין" עומד כיום על 50 מטר, רוחב שאינו מספק כרצועת מעבר לצבי הארץ-ישראלי ולאייל הכרמל. בהתחשב באורכו המתוכנן של מסדרון זה רוחבו חייב לעמוד על לפחות 100 – 150 מטר, על מנת שמינים אלה יעשו בו שימוש. בנוסף מחייב המסדרון פיתוח של מעבר תפקודי שיאפשר חצייה בטוחה של הכביש הראשי. נושא זה מחייב עיון וטיפול מפורטים יותר.

המלצות נוספות של הדו"ח כוללות הדגשת המעורבות הנדרשת של כל בעלי העניין בתהליך התכנון, פיתוח המחצבה ונקיטת צעדים ספציפיים לפיתוח "אזור עסקים ירוק". בעלי העניין חיוניים למימוש תכנית פיתוח הרמונית. מחצבת בנימינה, מדרום לרמת הנדיב, יכולה לתרום לגידול בית גידול חשוב, היכול לתמוך באוכלוסיות של בעלי חיים של מים מתוקים.

1 Introduction

1.1 Ramat Hanadiv

Ramat Hanadiv is located on the coast north of Tel Aviv, at the southern end of Mount Carmel (Figure 1). The area is dedicated to the memory of Baron Edmond de Rothschild. The area measures some 400 ha. Ramat Hanadiv Nature Park features a mosaic of different landscapes and habitats, both natural and manmade, like (planted) groves, dense maquis, open grassland, and rocky slopes. Nature management is intended to ensure the continued existence of the Nature Park's flora, fauna, and characteristic landscape. Thousands of visitors are attracted to the Memorial Gardens, the Nature Park, and the Visitors Pavilion.

Ramat Hanadiv has high biodiversity. The area has some 80 species of mushrooms (out of a total of 270 found in Israel); 47 species of butterflies (out of a total of 141 found in Israel); 37 species of birds (out of a total of 540 found in Israel); and over 620 plant species (out of a total of about 2,800 found in Israel). The richness of the species is particularly great considering the size of the area. Some of these include Cyclamen, Irises, Anemones, rare Allium species, Wild boars, Indian crested porcupines, Roe deer, Hyrax, and Jackals, to mention just a few.

Moreover, Ramat Hanadiv has a long tradition of ecological management and strict conservation (since 1984). Ramat Hanadiv is highly regarded and is acknowledged both in Israel and internationally for its conservation and research.

Figure 1
Location of Ramat Hanadiv, in North Israel; yellow pin indicating the park.

East of Ramat Hanadiv lays the 'industrial zone' of Binyamina, along the main road on the boundary between the park and the agricultural area. Few plots have been developed, seemingly haphazardly, with some garages/tyre centres, a riding school, restaurants etcetera. Also Zichron Ya'akov has prepared a plan for an

industrial zone. A green corridor is planned with a width of 50 metres, along the road, just south of the area. No information is available regarding fences or other infrastructure on the site. A few hundred metres East of Ramat Hanadiv, North of the agricultural area is also an industrial zone, which is fenced in, for security reasons.

Ramat Hanadiv is enclosed by roads on all sides and two highways are situated just west of the area, as is a railway line. East of Ramat Hanadiv is a busy regional road, which is being upgraded. To the North and the South are the villages of Zichron Ya'akov and Binyamina, which are continually expanding. With the expansion and upgrade of the industrial zone, Ramat Hanadiv will be virtually cut-off from the natural areas surrounding it. Just north and east of Ramat Hanadiv are protected areas; Park Alona Forest, and a Biosphere Reserve which are dense forested areas, both natural (maquis) forest, planted pine, and broadleaved forests. Further east of Ramat Hanadiv are also open grasslands used as a grazing area or used as a shooting range by the army. Just west of Ramat Hanadiv, is a wetland area with specific seepage issues, rare vegetation, and where soft-shell Turtles have been found.

Ramat Hanadiv and its 'hinterland' (inland area), were visited in April 2012 (Figure 2). A field visit served to check the variety and quality of the habitats for the selected species. The measure of fragmentation was visually assessed, as were the local conditions in and around Ramat Hanadiv, with a focus on the impact of the possible expansion of the industrial zone and changes in road infrastructure. In 2009, major infrastructure in the form of Highway 6 opened. The National Parks Authorities and concerned residents influenced the construction of the road, which resulted in an adjusted road alignment, and a number of passages for local roads and for wildlife. The wildlife bridges across Highway 6 were discussed with local experts during the visit, and some locations were visited to assess the functionality for- and impact on wildlife.

1.2   Problem Definition

The process of urbanisation has been on-going since the foundation of the State of Israel. Over the past twenty years, the process accelerated with the large influx of immigrants, resulting in an increased pressure on rural areas and the expansion of urban areas. Under current spatial planning regulations, municipalities are motivated to develop industrial zones, as this increases revenues. This increase in urban areas, infrastructure, and industrial zones results in a fragmented landscape.

Over the past decades, the development of the coastal region of Israel experienced a rapid urbanisation and fragmentation of the landscape. While once, Ramat Hanadiv was an organic part of the wider landscape, it is now more and more an island within agricultural fields, infrastructure, and urban and industrial areas. Now, just east of Ramat Hanadiv, two municipalities are currently preparing new industrial zones. As a result of this, Ramat Hanadiv will virtually be cut off from the hinterland.

This will impact on how the park functions and the long-term future of its nature. Flora and fauna populations will impoverish if there is no longer regular exchange with the natural areas further inland. Disasters like large fires (as occurred on Mount Carmel), can wipe out entire populations. The risk of extinction increases in particular for those species with large habitat requirements or species with limited mobility. Additional problems may include inbreeding for some species and as a result of climate change, larger natural climate fluctuations specifically in regard to rainfall and temperature. In Israel, the climate change is even more severe than elsewhere and in due time, this will result in losses of wildlife and plant populations. If Ramat Hanadiv is isolated, it will be significantly impacted.
The aim of this study is:
 – To assess the need and importance of connecting Ramat Hanadiv to the surrounding natural areas and larger ecosystem network in Northern Israel.
 – To assess ways to ensure that Ramat Hanadiv is connected to major protected areas in the region, through corridors and/or other measures relevant in the specific setting of Ramat Hanadiv.

Figure 2
Field visit by Alterra, April 2012. The GPS track (Garmin E-trex) indicates the route, assessed locations and habitat.

In this report, we present the results of a spatial analysis of the ecological network, and recommendations based on these results. The report describes whether fragmentation may pose a threat to the long term future of Ramat Hanadiv and in that case, what the lifelines are and what can be done to protect them. The ecological network is assessed to see whether available (fragments of) habitat are large enough for species to survive. This is done through an assessment of the habitat requirements of selected species and the connectivity of the landscape with the landscape ecological model- LARCH. The connectivity defines how easily species can move to other habitat patches, and is defined by the spatial configuration of the habitat patches. LARCH-SCAN is used to assess where the functional corridors are located. Based on the results, it is possible to define areas where corridors should be developed to optimise the landscape configuration for wildlife.
Also, advice has been given with regard to stakeholder involvement and the need for support from the community, mayors, regional planners, and visitors for the development of the ecological corridors.

Chapter 2 describes the method that has been applied, more specifically the LARCH model, and the species selected by a scientific group of advisors. The analysis results are presented in Chapter 3, including a discussion of the landscape connectivity and corridors. This is followed by discussion, in Chapter 4, and in the last Chapter recommendations and conclusions. An explanation of frequently used terms in the report is found below in paragraph 1.3.

1.3   Definitions of Terms

Connectivity: a measure which defines how easily species can move to other habitat patches.
Carrying capacity: the maximum population of a species that a specific ecosystem can support indefinitely without deterioration of the character and quality of the resource, i.e., vegetation or soil. The carrying capacity can often be found in literature, but will differ greatly. E.g., density or carrying capacity for the porcupine, from the Negev to Northern Israel, may differ by a factor of 4. As such, based on the quality and characteristics of the habitat within the modelled area and expert opinion, an estimate was made, and if necessary, adjusted to fit the results.

Dispersal distance: the capacity of most individuals of a species to bridge distances to new potential habitat. The dispersal distance for each species is in fact, infinite. (There is always a Roe deer that can, on rare occasions, disperse 350 km or more). A cut-off point of 95% is used, i.e., how far 95% of a species can disperse. In literature, dispersal data is rarely found. At most some indication of how far a new colonization is, is reported. So information is used from the LARCH database, or alternatively an estimate is made based on similar species.

Ecological network: a network constituted of physically separated habitat patches, for a population of a particular species or a set of species with similar requirements that exchanges individuals by dispersal.

Habitat: an area which can support living organisms for at least part of their life cycle.

Habitat patch: a spatially defined area of habitat for a species.

Key population: a relatively large, local population in a network that maintains one immigrant per generation.

LARCH: a landscape-ecological model (acronym for: Landscape ecological Analysis and Rules for the Configuration of Habitat) used to visualise the persistence of metapopulations in a fragmented environment.

LARCH-SCAN: (=Spatial Cohesion Analysis of Networks) assesses the spatial cohesion of each habitat patch, using habitat features and dispersal characteristics of a species.

Local population: a small population of at least one pair, in one or more habitat patches within the home range of a species. A local population on its own is not large enough to be sustainable. In this report, a local population is usually meant to define an area large enough (sufficient habitat) to support a local population.

Local distance: the local distance is the distance covered by a species in its daily movements. This is sometimes called the home range, but home range is usually the area utilized by the species from which, you can calculate the local distance.

Metapopulation: a set of local populations in an ecological network, connected by inter-patch dispersal.

Minimum Viable Population (MVP): a population with a probability of exactly 95% to survive 100 years under the assumption of zero immigration.

Network distance (or network gap-closing distance): maximum dispersal distance of a species within non-habitat (e.g., farmland).

Reproductive Unit RU (breeding pair): a reproductive unit is usually a pair, provided the sex ratio is equal. Scenario: an image of a possible or desirable future situation.

Spatial cohesion (landscape connectivity): a relative measure that can visualise the weakest and strongest parts in the ecological network of a certain species.

Viable population: a viable (or persistent) population has a probability of at least 95% to survive 100 years.

Industrial development East of Ramat Hanadiv

2 Analysis Method

2.1 Concept of Ecological Networks

Biological diversity is highly dependent on the quality, quantity, and spatial cohesion of natural areas. If wildlife is spread over a large area in small numbers, and if the remaining areas are too small, sooner or later, wildlife species will disappear. Fragmentation severely affects the abundance of species. To allow for repopulating or restocking of small areas and habitats, the areas need to be connected to the remaining core areas for wildlife in the vicinity (Jongman et al. 2011; Snep and Ottburg 2008). For birds, this means that the distance from source areas to their habitat is less than the normal distance they might cover when flying. For non-flying animals it might mean that a physical connection is required that functions as a corridor e.g., woodlands, streams, rivers, natural grasslands, and so forth (Grift et al. 2013; Van der Sluis et al. 2004).

An answer to this problem is the strengthening of an ecological network, linking nature areas by means of corridors and small habitat patches (Opermanis et al. 2012; Van der Sluis et al. 2004; Van der Sluis et al. 2003; Vos et al. 2001). An ecological network consists of habitat patches for a population of a particular species that exchanges individuals by dispersal.

The development of ecological networks is part of European policy (Bern Convention, Birds and Habitats directive) and has resulted in the development of the Pan European Ecological Network PEEN (Jongman et al. 2011). In the United States, this concept was developed and referred to as 'greenways' (Ahern 1995). Recently, the term coined in EU-policies for the same concept is 'green infrastructures'. Ecological networks can be especially beneficial for large herbivores like the Roe deer and gazelle, or for top predators like the wolf, leopard, lynx and otter. Corridors for large animals will also benefit many small organisms as a result of improvements in spatial cohesion and expansion of natural habitats.

To define the functioning of the ecological network, an analysis method has been developed based on the theory of metapopulation and ecological networks. The metapopulation theory states that in fragmented landscape populations, animal species do not live in a continuous habitat but in a network of habitat patches, which are mutually connected by dispersal movements (Andrén 1994; Hanski et al. 1997; Levins 1970; Opdam et al. 2002; Van Teeffelen et al. 2012). Whether or not an ecological network can sustain a persistent population depends on:
- Characteristics of a species: habitat preference, home range, and dispersal capacity
- The amount, shape, and area of habitat patches in a landscape
- Connectivity of the landscape, which defines how easily species can move to other habitat patches (spatial configuration of habitat patches)
- Resistance of the landscape (landscape matrix)

The function of a landscape as a network can be tested on the basis of a number of species, which can be attributed to an ecosystem type. The ecosystems that are evaluated, in fact, combine to form the landscape. To evaluate the functioning of the landscape for sustainable wildlife populations, the LARCH model is used.

2.2   LARCH Model

The landscape-ecological model, LARCH (Landscape ecological Analysis and Rules for the Configuration of Habitat), developed at ALTERRA, is a tool to visualise the persistence of metapopulations in a fragmented environment. LARCH provides information on the metapopulation structure and population persistence in relation to habitat distribution and carrying capacity. LARCH-SCAN assesses spatial cohesion of a potential habitat, and provides information on the best ecological corridors in the landscape. The LARCH model is run with a land-use map or vegetation map as input. In the next paragraphs the procedures of LARCH Model are explained in greater detail.

2.2.1   LARCH

LARCH is designed as an expert system, used for scenario analysis and policy evaluation. The model has been fully described elsewhere (Chardon et al. 2000; Franz et al. 2011; Groot Bruinderink et al. 2003; Pouwels et al. 2002; Van der Sluis and Chardon 2001; Van der Sluis et al. 2003b; Van der Sluis et al. 2007 ; Van Rooij et al. 2004; Verboom et al. 2001) and will only be discussed briefly here. A more extensive explanation is provided in Annex I.

The principles of LARCH are simple. A species, relevant for nature conservation or an indicator species representing a suite of species is selected, to assess the natural areas. The size of a natural area (habitat patch) and vegetation structure determine the potential number of individuals of a specific species it can contain. The distance to neighbouring areas determines whether it belongs to a network of the species. All areas in a network contribute to the population and depending on species characteristics, the size of the network population is determined. Based on that it is determined if the network population is persistent or sustainable for the species.

LARCH requires input in the form of habitat data (e.g., a vegetation or land-use map) and ecological parameters (e.g., home range, dispersal distance, and carrying capacity for all habitat types). LARCH parameters are based on literature and empirical studies. Simulations with the dynamic population model METAPHOR have been carried out to validate parameters and standards for the model (Chardon and Verboom 2001; Foppen et al. 1999; Opdam et al. 2002; Van der Sluis et al. 2003a; Verboom et al. 2001; Verboom et al. 1991; Vos et al. 2001). Actual species distribution or abundance data are not required for LARCH since the assessment is based on the potential for an ecological network of a species. It should be kept in mind that the results from LARCH present the potential distribution of a species, i.e., disregarding the quality of an area.

2.2.2   LARCH-SCAN

Beside surface area, the landscape connectivity or spatial cohesion is also important (Hanski et al. 1997; Verboom and Pouwels 2004). The surface area determines the expected number of individuals in an area, while the connectivity primarily depends upon the carrying capacity of a patch and the dispersal capacity of a species. The dispersal distance of a frog is much smaller than that of a large mammal, such as the red deer. In effect, this dispersal distance defines whether or not habitat patches will form part of a network for a species. A red deer might utilise forest areas within a radius of 50 kilometres, whereas a frog only utilises habitat within a radius of 300 metres from its breeding site.

LARCH-SCAN (=Spatial Cohesion Analysis of Networks) assesses the spatial cohesion of each habitat patch using habitat features and dispersal characteristics (Bruinderink et al. 2003; Van der Sluis et al. 2004; Vos et al. 2001).

LARCH-SCAN works with grid maps or square grid cells, for calculation purposes. The dispersal range of a species in a landscape can be described by a function in which alpha is the key parameter, describing the distance over which potential source patches can still deliver immigrating individuals (Hanski et al. 1997). The extent of potential habitat surrounding a cell that contributes to this measure of connectivity is determined for each grid cell. Here, the value of the potential habitat for a grid cell depends upon the carrying capacity (or the size) of the habitat. Because the method examines each individual grid cell, the degree of connection between habitats is considered in this measure, as are the surface areas of the habitats themselves. After all, a grid cell located in the middle of a very large habitat patch will have a high connectivity value. The spatial cohesion provides an insight into the degree to which areas are connected and to the potential for an area to function as a corridor for species. Roads (and barriers) have been taken into account in defining the spatial cohesion.

2.3 Base Maps

The area was checked during a three-day field visit in April 2012. In the same period, a number of datasets were acquired from different partners to create a land-use map for Ramat Hanadiv and its surroundings. Guiding principles for creating the map were:

1 Develop a map suitable for calculations of the LARCH model for selected species:
   • The scale of information should match with species (use of) habitat.
   • The map should support species habitat needs.

2 The map should reflect the regional approach:
   • Use of the (detailed) vegetation mapping of Ramat Hanadiv to create a legend which is useful in a wider context. The area of interest should be +/- 30 km max from RH.
   • The information should be comparable across the map.
   • Harmonise the use of available datasets.
   • Match available and mapped spatial planning perspectives.
   • A limited amount of land-use classes.

Figure 3 shows the approach for development of the final land-use map. Figure 4 shows the used input maps. Based on the guiding principles for the mapping, it was possible to create a land-use map with 47 classes (Table 1). The land-use classes are structured into seven main classes which are subdivided according to their vegetation, density, and naturalness. The map with the final land-use types used for the habitat classification is shown in Figure 6
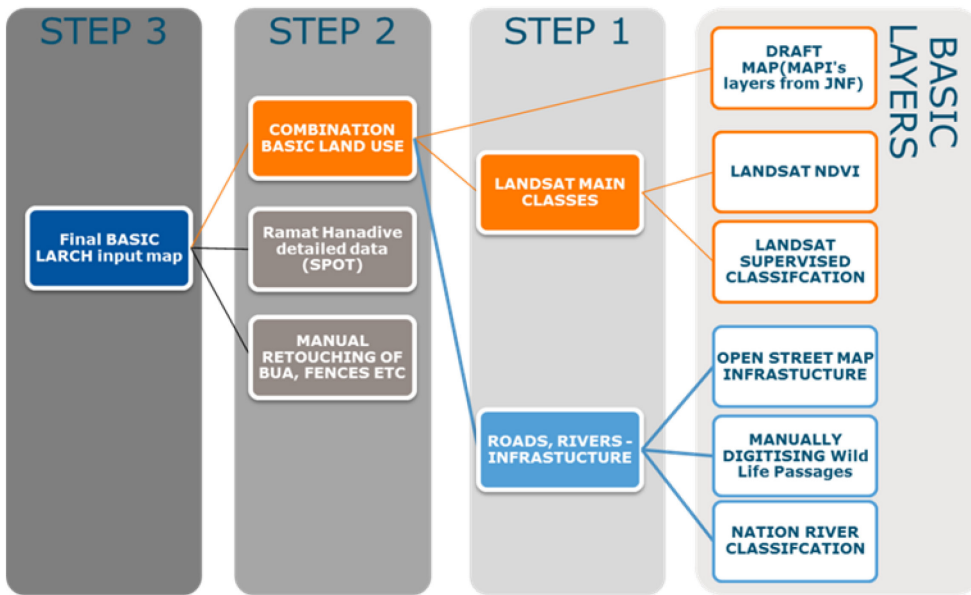
Figure 3

Stepwise approach to prepare the final land-use map for Ramat Hanadiv and its surroundings.
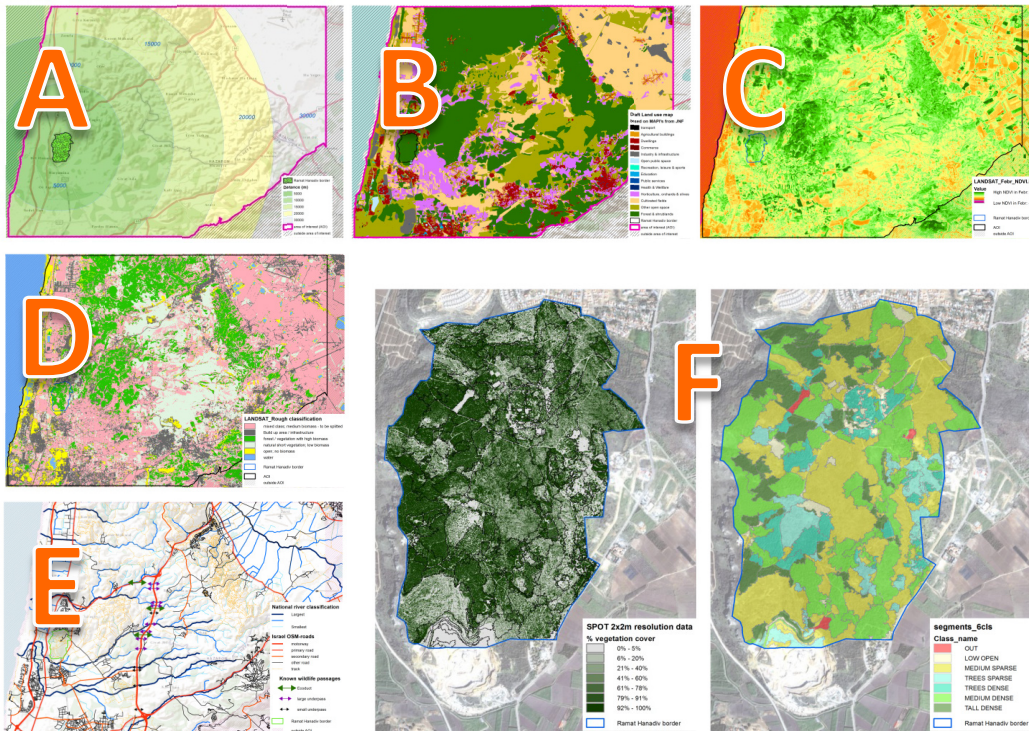

Figure 4

Used input maps: A: Boundary taken from map B, B: MAPI's basic land-use layers from JNF; C: Landsat NDVI image for February, D: Landsat classified in 6 main land-use classes, E: Roads and rivers from various sources (Open Street Map, National River classification), F: Detailed input data from Ramat Hanadiv (Classified Spot data densities and types).

2.4   Development Scenario

To analyse the impact of spatial developments around Ramat Hanadiv, the current situation is compared to a future vision, a scenario for the area. A scenario can contain many assumptions and many aspects of regional development. It was decided to focus on the measures that are central in the research question as defined in the project definition: What is the impact of the further development and expansion of the (two) industrial zones just east of Zichron Ya'akov and north of Binyamina. So we compare the current situation (Figure 5B) with a scenario in which the industrial zone and the improved road (Number 652) block the possible connection from Ramat Hanadiv toward natural areas in the East (Figure 5C). We assume, in fact, that Ramat Hanadiv would be more isolated from other populations. The road is not an absolute barrier for some species, although for most it is. In some cases, this will differ from the results for Ramat Hanadiv, standing on its own, forming an island (Figure 5A).

This scenario of industry development results in some loss of habitat (land which is transformed for industrial purposes), development of local infrastructure, and a restructuring of the road. As a result of the buildings and other infrastructure, some wildlife can no longer migrate toward the East. The restructuring of the road would probably result in a wider, upgraded road and more traffic. This would cause more wildlife casualties, affect the habitat quality near the road, and deter wildlife that would approach to cross the road.

Since other measures like expansion of settlements, expansion of farm buildings in rural areas, development of a possible nature corridor along the Taninim River etcetera, are not at all concrete at this stage, these were not included in the scenario. Another important reason is that this could confuse discussions as to which measures are realistic and which are not and what can be attributed to the impact of the industrial zone development.

Further, a map was developed with a corridor located through the industrial zone along the road (known locally as Derech Yafo) going southwest in the direction of Avi'el as a mitigating measure for the industry development. The corridor is part of the current plan for the industrial zone of Zichron Ya'akov with a planned width of 50 metres. This corridor is not yet developed. The map with the corridor is used for the assessment of landscape connectivity which will show whether a corridor has an effect on the wildlife populations.
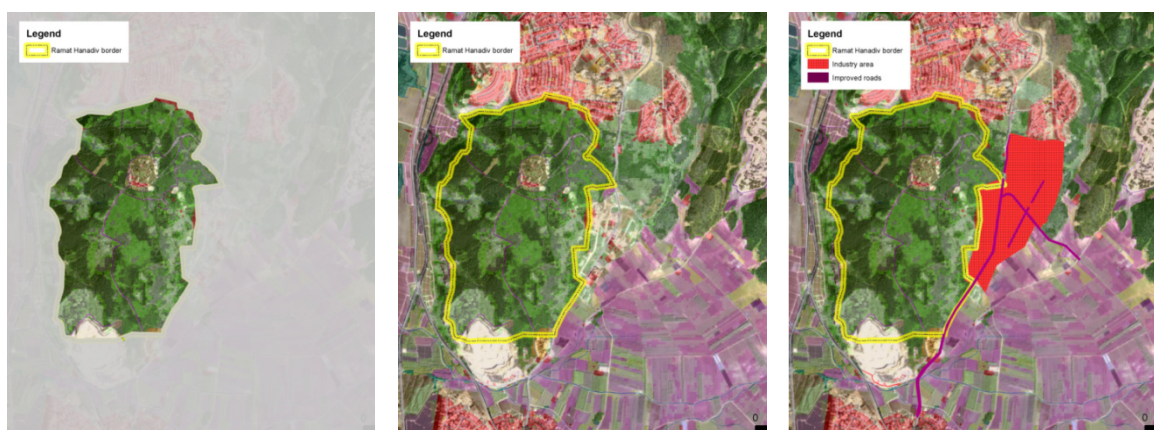
Figure 5

Graphical presentation of the calculated scenarios in Table 15: **A** *– RH as an island, no data outside the fence of RH.* **B** *– Current scenario RH is fenced, but this is permeable for all species at the network level.* **C** *– In the industry scenario, the road on the East side of RH is upgraded and no longer permeable for some species, and the industrial zone is blocking the easiest and shortest connection with the forest areas outside RH.*

Table 1

Land-Use Types Used for Habitat Classification.

| LSTYPE	Description
NR_1111	Cultivated Fields - Agriculture dominated by annual crops
NR_1112	Cultivated Fields - Agriculture with annual and perennial crops
NR_1120	Cultivated Fields - Predominantly agricultural grassland
NR_1201	Horticulture - Orchards & olives dominated by annual crops
NR_1202	Horticulture - Orchards & olives with annual and perennial crops
NR_2110	Grassland - Open (semi-)natural grassland
NR_2120	Grassland - Dense (semi-)natural grassland/open garrigue shrubland
NR_2130	Shrubland - Dense garrigue shrubland with trees
NR_2211	Forest - Open woodlands (semi-)natural
NR_2212	Forest - Open woodlands (park/planted)
NR_2221	Forest - Medium dense woodland/edge forest (semi-)natural
NR_2222	Forest - Medium dense woodland/edge forest (park/planted)
NR_2231	Forest - Dense woodland (semi-)natural
NR_2232	Forest - Dense woodland (park/planted)
NR_2240	Forest and shrubland in river banks
NR_2300	Wetland area
NR_3100	Water (predominantly fish- and water storage ponds)
NR_3101	Water (in urbanized areas)
NR_3210	River - Small ditch or stream (often seasonal water supply)
NR_3220	River - Larger ditch or stream (often seasonal water supply)
NR_3230	River -Larger ditch or stream (permanent water supply)
NR_4110	Infrastructure - Small track/path
NR_4211	Infrastructure - Other road
NR_4212	Infrastructure - Other road trough build up area
NR_4220	Infrastructure - Secondary road
NR_4230	Infrastructure - Primary road
NR_4240	Infrastructure - Highway
NR_4300	Infrastructure - Railroad
NR_4411	Infrastructure - Wildlife Crossing overpass large
NR_4412	Infrastructure - Wildlife Crossing overpass small
NR_4421	Infrastructure - Wildlife Crossing underpass large
NR_4422	Infrastructure - Wildlife Crossing underpass small
NR_4511	Infrastructure - Fence high (non-permeable)
NR_4512	Infrastructure - Fence high (permeable)
NR_4521	Infrastructure - Fence low (non-permeable)
NR_4522	Infrastructure - Fence low (permeable)
NR_5110	Built up area
NR_5120	Industry & infrastructure
NR_5200	Public space
NR_5300	Areas with urban use
NR_6110	Other land-use - Sparsely vegetated areas
NR_6120	Other land-use - Little or no vegetation
NR_6130	Other land-use - Shrubland and trees
NR_6140	Other land-use - Bare rocks on steep slopes
NR_7100	Memorial Garden
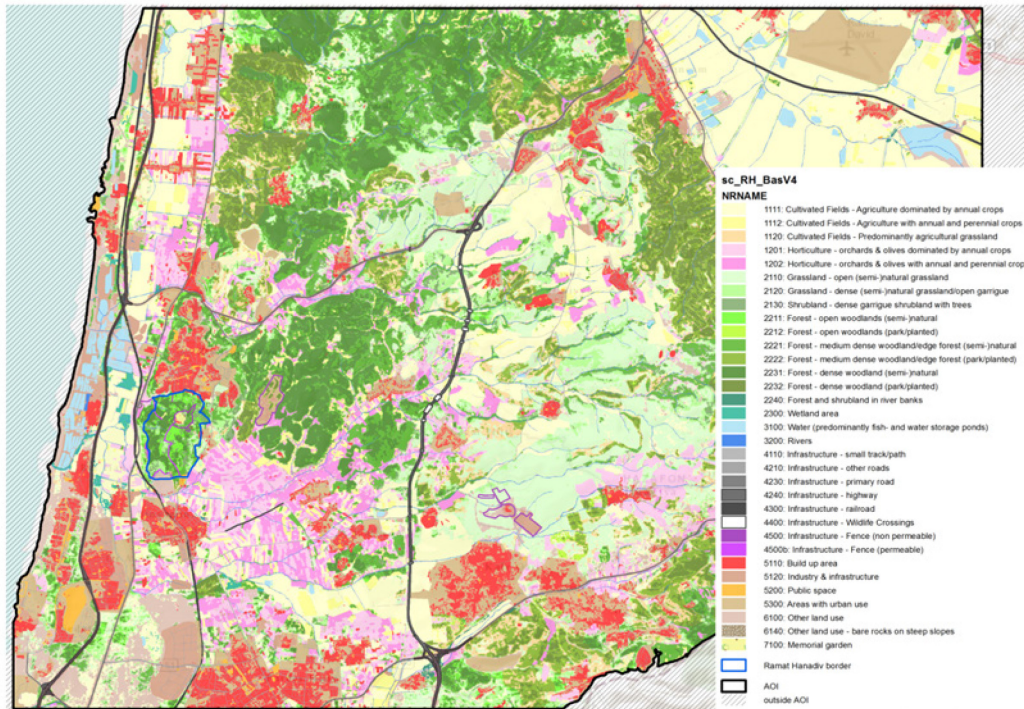
Figure 6
The map which forms the basis for LARCH modelling.

2.5   Species Profiles

The analysed ecosystems are woodlands, shrubland / maquis, and grasslands. The viability for a number of representative species for these ecosystems which are sensitive to fragmentation was assessed. A list was prepared with potential species for analyses with the LARCH model. These species were discussed with a group of local experts including the park manager, species specialists, the park technical advisor, and a ranger from the National Parks Authority (NPA). Based on this discussion, nine species were selected which is a broader selection than the five originally selected species.

The selected species are:
- Large mammal: Mountain gazelle, Roe deer
- Medium-sized mammal: Badger, Fox, Indian crested porcupine
- Small mammal: Yellow-necked mouse
- Butterflies: False apollo/Eastern festoon
- Birds: Chukar partridge
- Reptile: Armoured glass lizard

The species data/parameters for modelling are derived from literature on the region. These parameters are critically compared with literature from elsewhere. If no specific parameters are available, data from the LARCH database is used. If this is not available, e.g., for Armoured glass lizard, information from a similar species is used. The reliability of the data is indicated in the results.

The selected species differ in their dispersal range and habitat requirements. The range of species varies from less than one kilometre to a range of 15 kilometre or more. Similarly the habitat requirements for a key

population differ e.g., the Yellow-necked mouse will persist in a relatively small area of a few hectares, whereas a Badger requires extended areas for foraging. In Table 3 the position of the species is indicated.

Table 2
Species selection and ecosystems.

English name	Hebrew name	Scientific name	Forest	Shrubland	Grassland
Roe deer	אייל כרמל	*Capreolus capreolus*	X	x	
Badger	גירית מצויה	*Meles meles*	X	x	x
Fox	שועל מצוי	*Vulpes vulpes*	X	X	
Indian porcupine	דרבן הודי	*Hystrix cristata*	X	x	x
Yellow-necked mouse	צוואר יערון צהוב	*Apodemus flavicollis*	X	X	
Mountain gazelle	צבי א"י	*Gazella gazella*	x	X	x
Armoured glass lizard	קמטן החורש	*Ophisaurus apodus*		X	x
Chukar partridge	חוגלה	*Alectoris chukar*		x	X
False apollo / Eastern festoon	צבעוני שקוף צבעוני / קשוט	*Archon apollinus / Allancastria cerisyi*			X

Table 3
Dispersal distance and habitat requirements for selected species, and attribution to ecosystems: Woodland, Maquis/Shrubland, Grassland & Steppe.

Ka \ Nd	<1	1-3	3-7	7-15
0-1				
1-5	Armoured glass lizard Yellow-necked mouse False apollo / Eastern festoon	Roe deer Mountain gazelle		Chukar
5-10		Crested Porcupine		
10-50		Badger Fox		
50-150				

KA = key area (km^2), ND = network distance (km)

2.5.1 Woodland

Roe deer (Capreolus capreolus)

The Roe deer has been extinct from Israel for over 100 years. It, amongst others, was recently re-introduced in Ramat Hanadiv. From 1997 to 1999, 14 animals were released in total (http://www.lhnet.org/eurasian-roe-deer/). Boitani, the Italian national expert, has suggested that the Roe deer is a keystone species (Wallach et al. 2007), which underlines its significance for the ecosystem.

The Roe deer population is defined by the number of females that form harems and are dominated by males maintaining a territory (as with gazelle). It seems, that water availability is a stronger limiting factor than food availability (Wallach et al. 2010; Wallach et al. 2007). In favourable habitats, density may range from 10-20 individuals/100 ha (Mitchell-Jones et al. 1999). Similar figures were found in other studies, 17.03 (José and Lovari 1998). For Southern France (Luberon), a mean home range of 157 ha was found (Maillard et al. 2002). In this same area, dispersal was calculated and 75% of adult Roe deer remained within four kilometres of the release site. The largest dispersal distance was covered by an adult female that settled down 20 kilometres from its release site. Age had a significant effect on the distance of dispersion of the deer (Calenge et al. 2005). Other studies showed an average home range size of 33 ha, with a wood quantity of 11.6 ha (Lovari and San Jose 1997).

It is very difficult to estimate the real optimal species density because the species was reintroduced. In the Netherlands the average density is 33 RU/100 ha, which is similar to other European countries. The estimate used for Ramat Hanadiv is 6RU/100 ha. Some experts from Israel estimate the density at 2 RU/100 ha, but this as defined, results in a population which is not viable even at the scale of the entire region.

The potential population of the Roe deer in Ramat Hanadiv could be up to some 40 animals. Although this may be considered by some as a very high estimate, the parameters used are conservative (at 20% of numbers used elsewhere) and the population is most likely still growing.

Badger (Meles meles)

The Badger favours natural habitats since shrub cover and rocky terrain provide it with good shelter. Croplands and orchards are avoided as are areas with human presence and industrial zones (Lara-Romero et al. 2012).

In Mediterranean Spain, Badger densities ranged from 0.23 to 0.67 individuals /km². These densities are between five and 125 times lower than that of populations inhabiting temperate ecosystems, where badgers feed on earthworms (Revilla et al. 1999). In Southern Italy, the species has a density of 0.05 - 0.47 families/km² (Mitchell-Jones et al. 1999). For modelling, in Umbria we used home range of 2000m, dispersal distance of 30000m, density of 0.750 RU/100ha, and minimum area size of 10000m² (Van der Sluis et al. 2003).

The Badger population of Ramat Hanadiv may be some 20 individuals, but considering the structure of the population, there may be some 10 reproductive units (Ramat Hanadiv- staff information).

Fox (Vulpes vulpes)

The Fox is an omnivore and habitat generalist. The natural habitat for this species is dry, mixed landscape, with an abundant "edge" of scrub and woodland. It is a solitary hunter, which preys on small and medium-sized mammals (e.g., rodents and lagomorphs) and periodically on invertebrates, birds, carrion, and fruit.

The density values were identified by the studies of Cavallini and Lovari (1994) and Pandolfi et al. (1997). These studies were conducted in Italy, where ecological characteristics such as vegetation cover and climate are quite similar to the study area in Israel. The estimated parameters used for the calculation of carrying capacity is a density of 2 foxes/km² (Pandolfi et al. 1997) or 1RU/100ha and a home range of 268.7 ha (Cavallini and Lovari 1994; Pandolfi et al. 1997). In Hungary the calculated mean density of the red Fox was estimated at 2.4 individuals/km² (Lanszki et al. 2006).

Only some 10 RU (Reproductive Units) occur in the area of Ramat Hanadiv (Ramat Hanadiv- staff information).

Indian crested porcupine (Hystrix indica)

The Indian crested porcupine is found in the Eastern Mediterranean and Central Asia. It therefore differs from the (North African) Crested porcupine, Hystrix cristata, which is found in Africa and Italy. Its habitat consists of rocky hillsides, shrubland, grasslands, forests, arable land, plantations, and gardens. It breeds in burrows and dens and their territories largely overlap (Sonnino 1998). They are generalist, opportunistic feeders, and feed on tubers and roots of mostly geophytes, including food crops such as potatoes, peanuts, and others (Alkon and Olsvig-Whittaker 1989).

The population densities vary across its range, and in some areas it is considered a pest. There have been declines in some areas probably as a result of persecution and exploitation for its meat and quills. (IUCN). In Israel it is also hunted for its meat.

Average home range sizes differed, being 135 and 57 ha respectively, and 96 ha on average. Apparently these range sizes for the Indian crested porcupine are half the size of ranges in the Negev Desert, which is some 4 adults/km² (Alkon and Olsvig-Whittaker 1989) or 2 RU/100 ha. In Italy, they make foraging expeditions of 10-12 kilometres per night (Santini 1980).

Some 30 porcupines from several family groups are found in Ramat Hanadiv (Ramat Hanadiv- staff information).

Yellow-necked mouse (Apodemus flavicollis)

The Yellow-necked mouse is primarily a species of mature deciduous woodland, although also inhabits other forest habitats. The species avoids intensive cultivated lands. In Eastern Europe, over 100 individuals / 100 ha are observed (Mitchell-Jones et al. 1999). It feeds on seeds, in particular tree seeds and fruit, but the mouse also preys on invertebrates. In Serbia, numbers ranged from two to 32 individuals/ha, with an 'average' density of 24 individuals/ha (1200RU/100ha) (Vukićević-Radić et al. 2006). Here the range of (recaptured) mice varied from 10 to 134meter, with a median value of 40.6 meter.

At Ramat Hanadiv, the mouse is observed in the well-developed Mediterranean scrub forest (Oak and Barzite) (Lehmann and Perevolotsky 1992). No information is available on its population size in the park.

In Nahal Oren the species is mostly trapped on north facing slopes, and in particular in the slightly drier Quercus ithaburensis and Pinus halepensis forests (Blaustein et al. 1996). The mice are found in burned woodlands as well, and are occasionally found on the wadi floor. Mobility seems limited (Blaustein et al. 1996).

Detailed analysis of habitat preferences was done for Serbia which reveals a preference for mature deciduous forest (oak forest) or for open canopy with mature deciduous trees (Vukićević-Radić et al. 2006).

2.5.2   Maquis - Shrubland

Mountain gazelle (Gazella gazella gazella)

The gazelle is both a grazer and a browser, depending on the season (Dijkstra et al. 1987; Geffen et al. 1999) but also adjusts its behaviour as a result of hunting pressure (Levins 1970). Female groups of gazelles are open units, moving freely over territories of male gazelles. The females make up the majority and only some 20% of males maintain their own territory. The reproductive units are therefore defined by female gazelles. The gazelle's main predators are the golden jackal and feral dogs. Also, road kills may have some impact at Ramat Hanadiv.

Under natural conditions, density of gazelles is some 13/km² (Ramat Qedesh, in Dijkstra et al. 1987). Baharav estimated 14-16/km², and Professor Mendelssohn estimated 10-15/km² (personal communication.)

Under more arid conditions, for example in Arabia, densities can be much lower, ranging from 0.935 to 1.935 gazelles/km² (Wronski 2010).

Specific studies were done for Ramat Hanadiv, indicating an average home range size for female gazelles of 16.5 ha or 6 RU/100 ha (with a range of 10.9-24.3 ha) (Geffen et al. 1999). The gazelle population was some 60 animals on 4.5 km², which equals a density of 10 RU/100 ha, but now there are probably at most 40 (Ramat Hanadiv- staff information).

Armoured glass lizard (Ophisaurus apodus)

The Armoured glass lizard is a legless lizard. It is an opportunistic feeder that feeds on snails, insects, arthropods, and occasionally on small mammals and lizards, etcetera. The species prefers (dense) shrubland (maquis) and dry areas, with few or no trees and ample opportunities for shelter like shrubs and stone heaps. Wasteland, thorny thickets and deteriorated walls also provide good cover (Petzold 1971). They are found in

hot places and particularly on south or east facing slopes (Strijbosch et al. 1989). The Armoured glass lizard is very vulnerable on roads. Even on sand roads they often fall victim to traffic (Petzold 1971; Strijbosch et al. 1989).

No densities were found for the lizard, except for a report of 80-100 specimen on a one-day excursion (Böhme 1981). The Green lizard (Lacerta virides), a species with similar characteristics and body mass, was selected as basis for the parameters. For this species, a density of 100 RU/100 ha was used   (Van der Sluis et al. 2003a; Van Rooij et al. 2003). The home range for Green lizard may be up to 100 metres with a network distance of up to 200 metres for Italian conditions.

2.5.3 Grassland and Steppe

False apollo / Eastern festoon *(Archon apollinus / Allancastria cerisyi)*
This profile is in fact based on two species of butterflies that may show some similarities in behaviour and habitat preferences. However, it is a general description since limited information is available, and where necessary, characteristics were used of other butterfly species.

The Archon has shown a decrease in European distribution area of 20-50%, and is therefore considered endangered. The species is found in Europe in Turkey and Greece only. The species has a preference for warm sheltered places in dry, rocky grasslands, and mixed and coniferous forests (Montoya et al. 2006). Its food plants consist of Aristolochia species. The species is threatened by agricultural activities, and in particular by intensification which resulted in a decline of food plants. Also housing development, chemical pollution, and fragmentation are mentioned as causes of decline (Montoya et al. 2006). Allancastria cerisyi is found in Southeast Europe. It is quite local and rare – and is declining over the whole range in the USSR (Collins and Morris 1985). Also Allancastria feeds on various Aristolochia species. We have no information on home range or dispersal distance. The population densities in optimal habitat for both the Archon apollinus bellargus and Allancastria cerisyi speciosa is some 25-30 butterflies at 60 square meter (Ramat Hanadiv- staff information). There is no information on the total population of these species in Ramat Hanadiv.

Chukar partridge *(Alectoris chukar)*
The Chukar is a bird of semi-arid hillsides, covered in low grasses or herbs and occasional trees and bushes. It may also inhabit vineyards, olive groves, agricultural land, and rocky slopes. The species is found in a belt with a steep gradient of climate and precipitation (Kark et al. 1999), in the Mediterranean, steppe, and desert zones.

Birds will travel several kilometres to drink. Densities may be 1-5 RU/km² under natural conditions, but if increased water is available the densities may be as high as 50 RU/km², following desert irrigation in Israel (Hagemeijer and Blair 1997). The Chukar's population in Ramat Hanadiv is estimated at some 200 birds (Ramat Hanadiv- staff information).

Below is a summary of the model parameters (Table 4) which are specific for Ramat Hanadiv. The local distance and network distance is partly dependent on landscape configuration (and thus map detail) which is specific for this project. The density (in pairs or Reproductive Unit) reflects the density in optimal habitat.

Table 4

Summary data for modelling for Ramat Hanadiv.

Species	Local distance (m)	Network distance (m)	Density (RU/100 Ha)
Roe deer	500	2.000	6.0
Badger	400	1.200	4.0
Crested porcupine	250	2.500	5.0
Gazelle	400	1.000	10.0
Fox	500	2.500	2.5
Yellow-necked mouse	150	1.000	50
False apollo / Eastern festoon	150	750	150
Chukar partridge	1.000	15.000	40
Armoured glass lizard	50	200	75

'natural' wildlife overpass across Highway 6

3 Results Spatial Analysis

3.1 Introduction

The LARCH analysis focuses on the development and sustainability of viable populations. This is based on species-specific parameters or characteristics, as well as empirically defined parameters (Verboom et al. 2001). The most viable situation for a species population is one large area of optimal habitat, large enough for a Minimum Viable Population (MVP). A MVP is defined as a population for which the chance of extinction is less than 5% in 100 years. Such a population is considered to be 'viable' in the long term. Slightly less viable is a key population, which is defined as a population which is viable under the condition of one immigrant per year. Otherwise, we consider an area a 'small population' if the area within the home range of a species is large enough for at least one breeding pair (Verboom et al. 2001).

A fragmented population occupies different habitat patches that can still be viable. Viability norms in LARCH are dependent on the presence of a key population and the total size of the population as shown in Table 5. Exchange between populations implies that areas are somehow connected (often through corridors) and form a metapopulation.
In principle, one larger and connected habitat is more viable than smaller fragmented habitats of the same size. In order to achieve viability, more habitat is required in a situation that is very fragmented and less habitat is needed in the case that one extensive natural area exists which is large enough for a MVP (Figure 7).
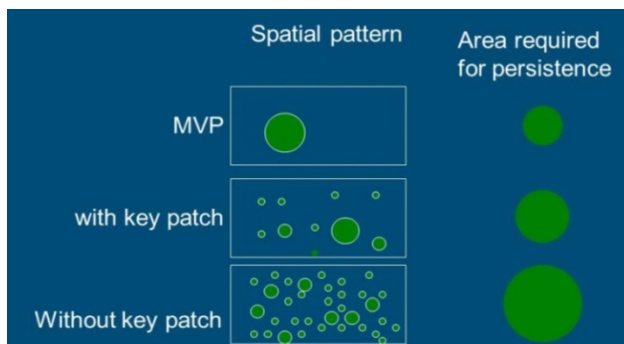

Figure 7
Sustainability of fragmented populations in relation to habitat distribution, spatial pattern-, and total required

In this chapter, we discuss the results of the analysis. Two maps are presented per species. The first map shows the local populations in relation to available habitat for the current situation, without a corridor or specific measures to improve the ecological quality of the environment.

The second map shows the viability or persistence of these networks i.e., the populations that possibly exchange and together form a metapopulation. For these networks it is indicated whether they are too small, not viable, viable, or strongly viable (for standards see Table 5). A population is considered viable if the chances of extinction are less than 5% in 100 years (a generally used criterion), a standard which is based on stochastic processes as well as genetic decline. In this case, the situation with the industrial zone is assessed.

The presented maps include: the current situation without industry and population viability with industry. Not presented in the report for clarity purposes, are the current situation with industry, and population viability without industry.

> Local populations:
> An area may consist of different small patches that are all within range for a species. When the area is '**too small**' for at least one (breeding) pair, it will be 'vacant', not occupied.
> If the total area is large enough, it can form a '**small population**', which may be a population of at least one or more breeding pairs.
> Some areas may be large enough to hold a '**key-population**', that forms a key for a viable population (see Definitions, par. 1.3) and for which the thresholds per species group differ (Table 5).
> Some areas, in relation to the area and population needs of a species, are large enough to hold an **MVP**, which is considered sustainable under all conditions.
>
> NB: Annex 1 illustrates the steps of the analysis

In pararagraph 3.3 the spatial cohesion for the landscape is calculated (see par. 2.2.2, LARCH-SCAN). This was done for Roe deer, a critical species for which the landscape connectivity is particularly relevant.

Table 5

Standards for Key Population size and Minimum Viable Population sizes in configurations with or without Key Population (all in Reproductive Units RU) (Verboom et al. 2001)

Species group	key population(KP)	viability with KP	viability without KP
Short-lived/small sized vertebrates	100	150	200
Middle long-lived/medium sized vertebrates	40	120	200
Long lived/large vertebrates	20	80	120
Invertebrates	500	1250	1250

In the following paragraphs, the results for each species are discussed for the current situation as well as for the situation with the industrial zone (scenario). The results are organised per ecosystem.

Two points should be kept in mind when interpreting the LARCH results:

(1) LARCH assesses the potential situation i.e., the situation in which habitat is considered optimal. An area assessed as suitable might not always correspond with the actual presence of a target species in that area. In reality, the situation might be much more complex than can ever be predicted with models.

(2) In order to advise on the quality of the proposed network and landscape connectivity, we look at multiple species at a given time, and try to extract a 'general' result for the modelled species for this specific ecosystem. The species are therefore to be seen as 'indicative' for a number of species. This result is of much greater importance than the result for a single species.

3.2 Model Results

3.2.1 Woodland

Roe deer

Populations

The Roe deer makes up a potentially small population in Ramat Hanadiv, as well as in the Alona Forest further to the East. The Carmel area in the North is potentially large enough for a key population of Roe deer. Industry development does, to a small extent, affect the available habitat, but overall the impact seems limited. The road poses a threat to the crossing of Roe deer into the farmland areas.

Viability of the Network

The potentially small population of Roe deer at Ramat Hanadiv alone would not be viable in the long run, since the population is too small. However, provided the areas form a network and Ramat Hanadiv is connected with the rest of the region; it will result in a potentially viable network.

The main connection with Ramat Hanadiv is however, located exactly at the proposed industrial zone. If this connection is lost, the population of Roe deer in Ramat Hanadiv will be isolated from the rest of the region and will no longer be viable. This means that the species is very likely to become extinct in the long term.

Discussion

Ramat Hanadiv is the source population, which is well protected. A normal expansion of the species into the region is important to avoid extinction.

The realization of the new industrial zone would be detrimental to the Roe deer population. The one existing connection would be disrupted by the planned development and would cut-off the lifeline for this population.

The Roe deer was reintroduced in the recent past at Ramat Hanadiv. To ensure that the population can expand and remains large enough (to decrease the risk of extinction) a connection with the regional population and hinterland is very important and a corridor is essential for this species.

Considering the ecological knowledge of the species and the spatial data, the modelling is considered reliable.

Table 6

LARCH analysis results for Roe deer. Population assessment and network viability assessment

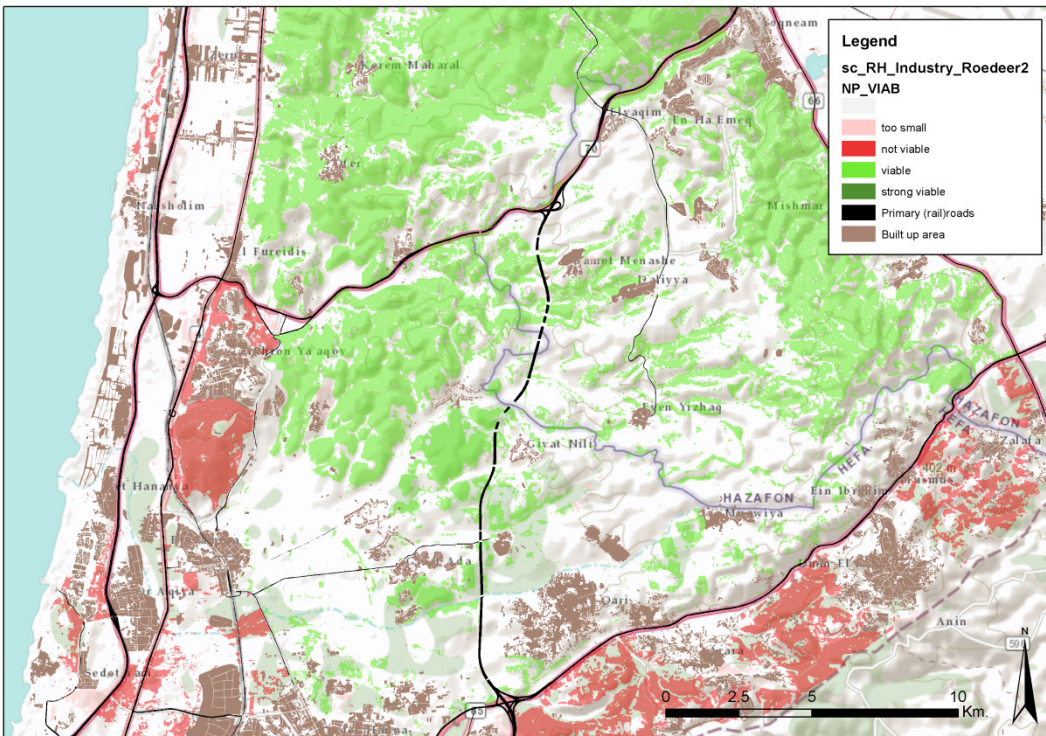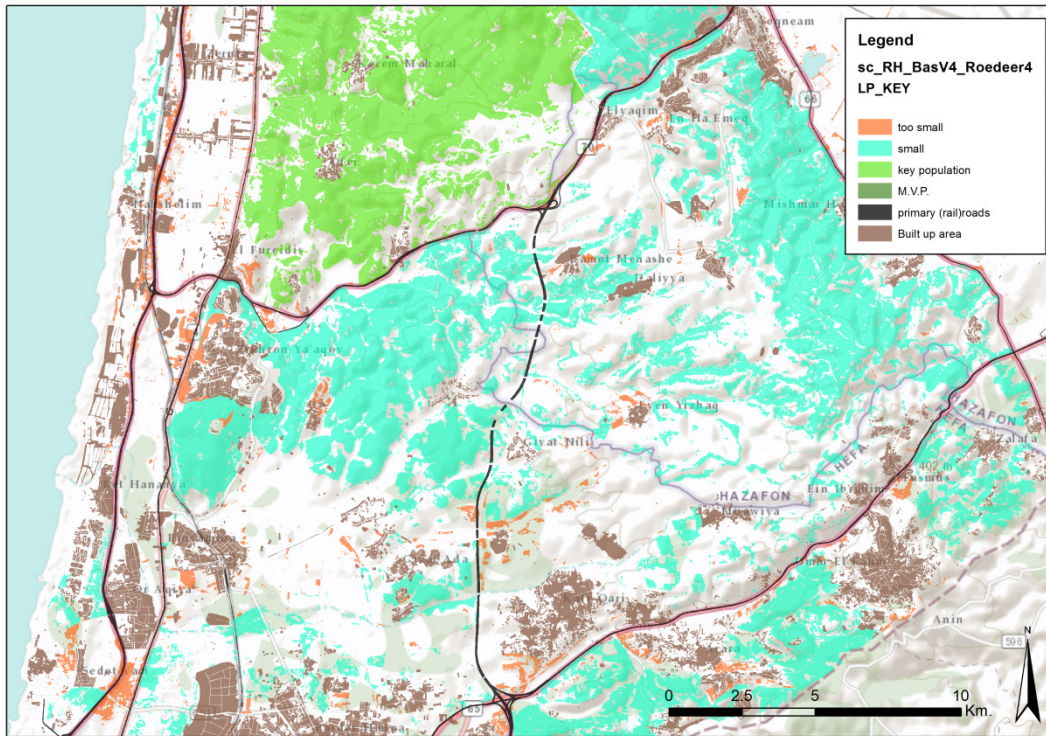| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' RH	RH isolated as an island
Roe deer	small	small	viable	not viable	not viable

Figure 8
LARCH model results for the Roe deer. Map above shows the size of the local populations for the current situation. Map below shows the viability of the metapopulation if the industrial zone is developed.

Badger
Populations
Ramat Hanadiv has a potentially small population of badgers, which is not sustainable on its own. Also in the coastal plain and the area further south the habitat is both small and fragmented and usually not sufficient for badgers. The population of Ramat Hanadiv forms a network with other populations in the region. The connection is based on both dispersal through agricultural fields and semi natural areas. In the industry scenario this connection is lost and only a weak connection through the agricultural fields remains, which is also under high risk and includes a road crossing.

Viability of the Network
As a result of the large habitat requirements of the badger, Ramat Hanadiv alone would be too small for a viable population. The population is viable due to exchange with other populations which takes place through the forested areas, but also through agricultural fields. After development of the industrial site, the population remains viable. However, the link with other areas is much weaker since migration will have to take place over long distances through farmland.

Discussion
The Badger is very vulnerable to roads, so the industrial zone is likely to have a large impact. The population will be more vulnerable due to the longer migration distance, but also because of the increase in mortality due to traffic, when crossing the road.
Not all of the area is suitable for the burrows of badgers. The modelling of badgers ideally involves a map, defining the existing burrows, or at least the areas suitable for burrows. *With such a map modelling can be improved. Also it is not clear how much use the Badger makes of farmland in this area. Considering the ecological knowledge of the species and the spatial data, the modelling is considered reasonable.*

Table 7
LARCH analysis results for the Badger. Population assessment and network viability assessment.

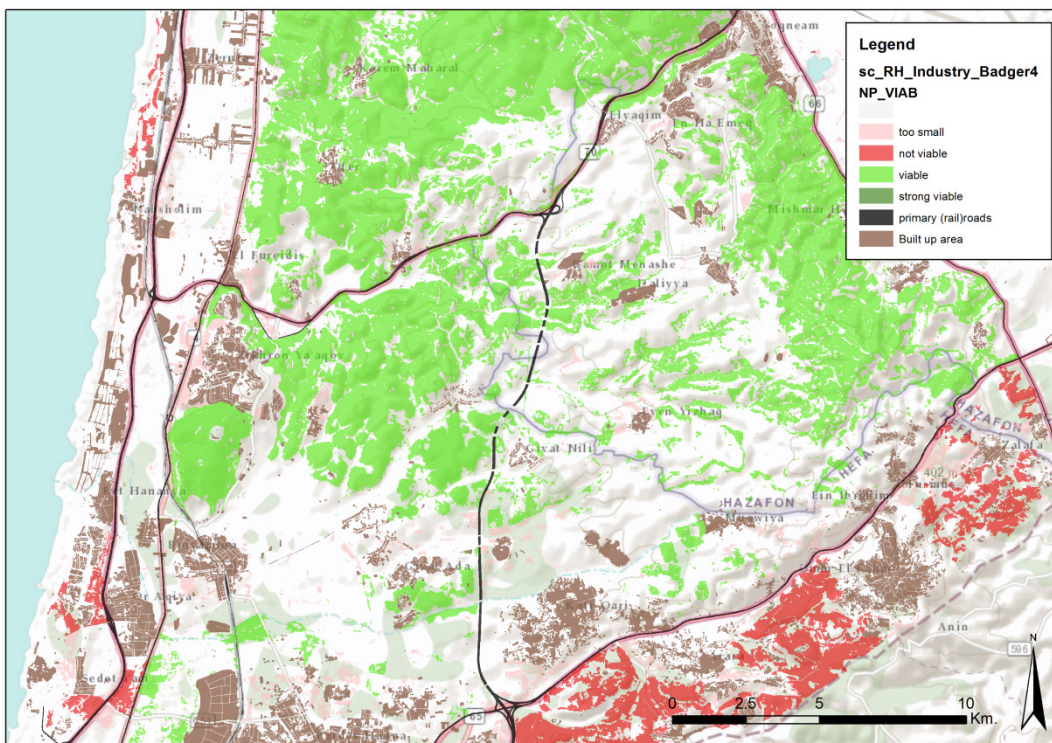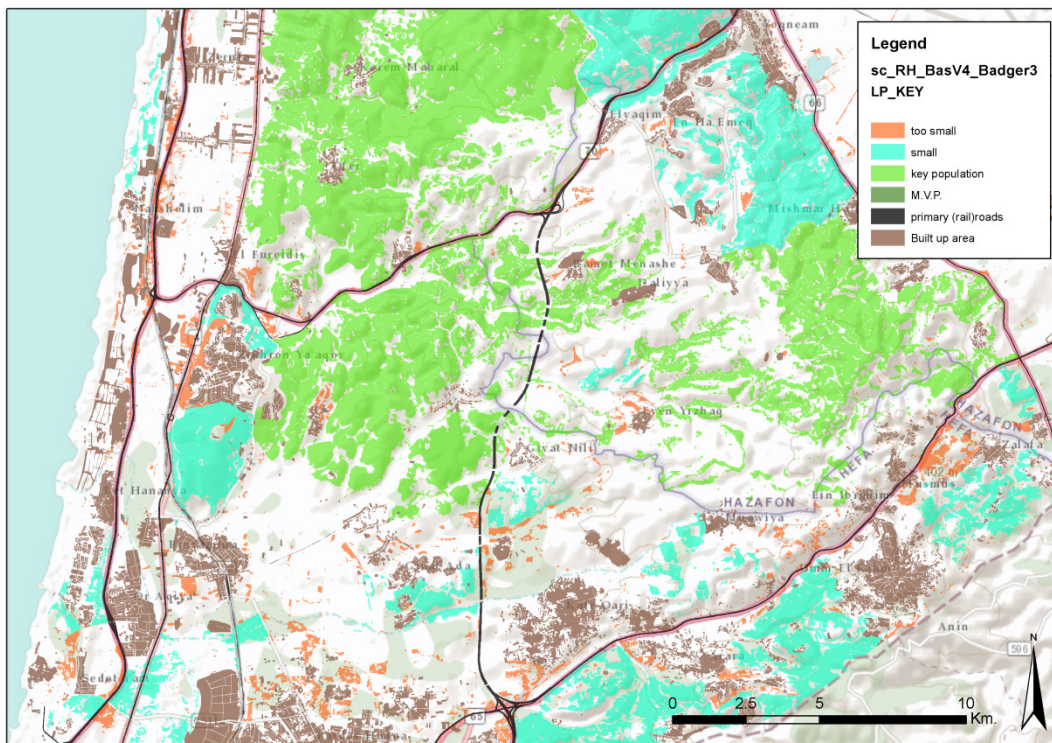| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' RH	RH isolated as an island
Badger	small	small	viable	viable	not viable

Figure 9

LARCH model results for the badger. Map above shows the size of the local populations for the current situation. Map below shows the viability of the metapopulation if the industrial zone is developed.

Fox

Populations

The foxes in Ramat Hanadiv form a small population which are part of the regional network. The scenario has limited impact on the Fox population. It remains a small population.

Viability of the Network

If Ramat Hanadiv were to stand on its own, because the area is only large enough for a small population, the population would not be viable. However, the Fox population is viable as part of the larger network.
In the scenario with a new industrial zone, the Fox population in Ramat Hanadiv will be more isolated from the rest of the region. The connection (dispersal through the adjacent semi-natural areas) will be lost and only a weak connection through the agricultural fields remains. Thus, animals are under threat. Foxes are often persecuted and killed in farmlands.

Discussion

Due to the low density of foxes, the population forms a true network population or metapopulation. Provided the area remains connected with other areas, the species is viable. However, migration through farmland is not the preferred option.
The Fox is a fairly flexible species, and can easily adapt its behaviour around people. Therefore there is some uncertainty, but considering the ecological knowledge of the species and the spatial data, the modelling is considered reliable.

Table 8

LARCH analysis results for the Fox population assessment and network viability assessment

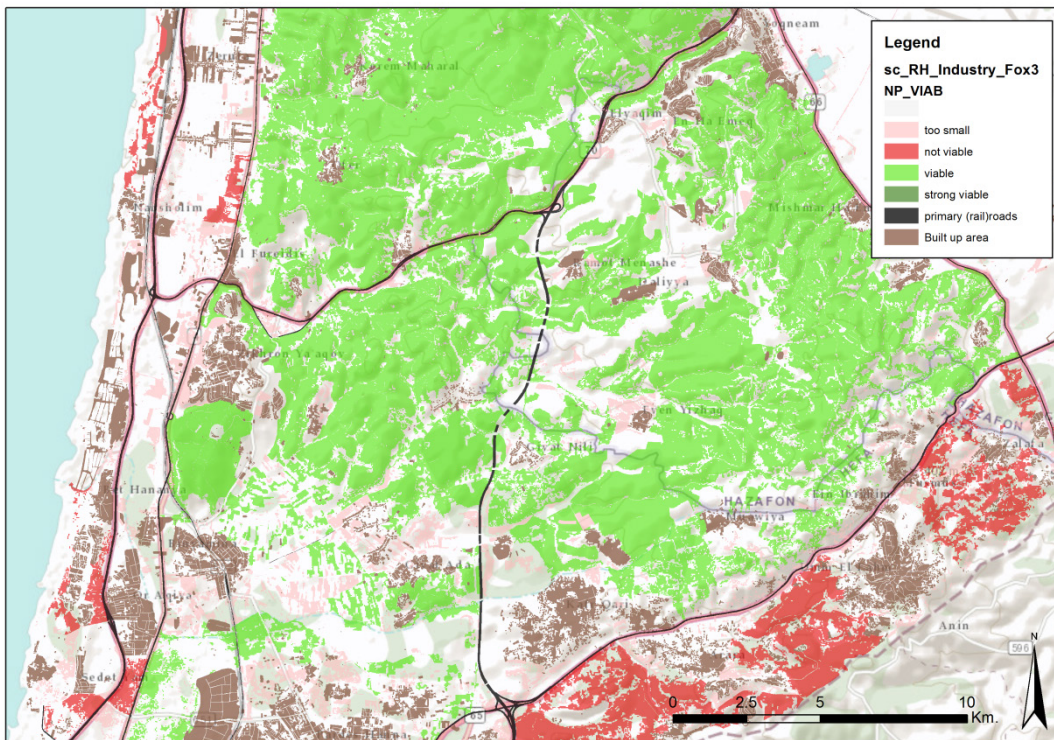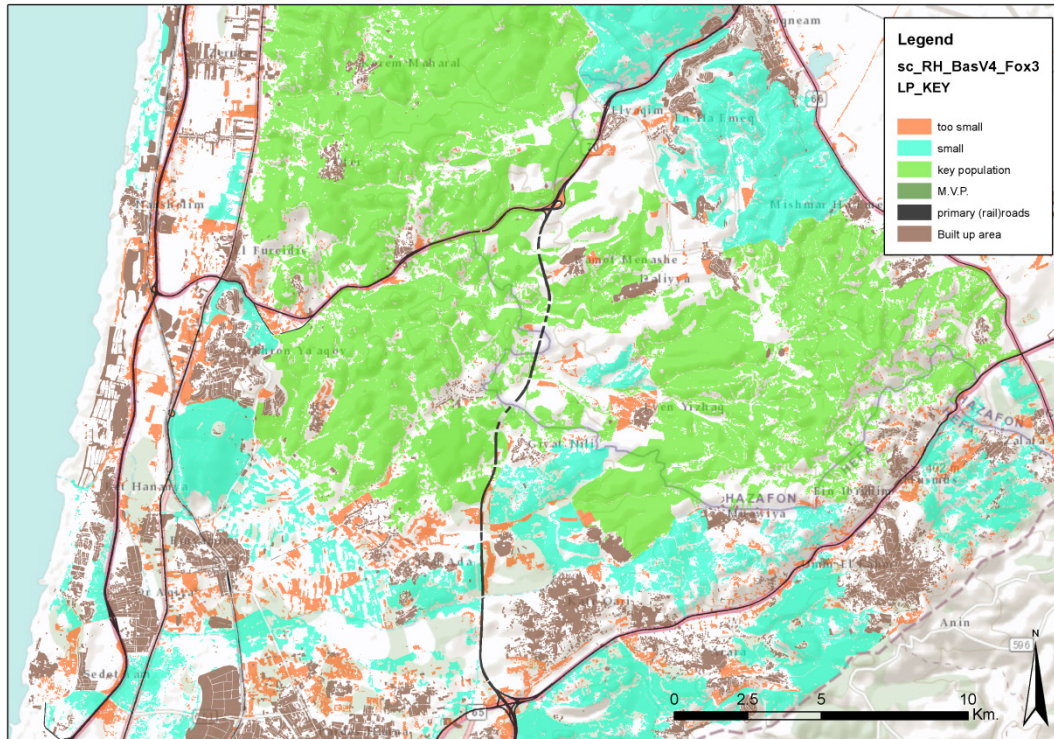| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' RH	RH isolated as an island
Fox	small	small	viable	viable	not viable

Figure 10

LARCH model results for the fox. Map above shows the size of the local populations for the current situation. Map below shows the viability of the metapopulation if the industrial zone is developed.

Indian crested porcupine

Populations

The Indian crested porcupine make up a small local population of some 10 RU. The development of the industrial zone does not significantly change the size of the local population(s). However, the potential connection to the East is almost lost due to the new industrial zone. Porcupines are vulnerable to barriers. Once the industrial zone is developed the area will be surrounded by roads.

Viability of the Network

The population of Ramat Hanadiv alone would not be viable. The species requires a connection to other populations to survive in the long term. Currently, and in the scenario situation, the population of porcupine in Ramat Hanadiv forms a potentially viable network. The development of the industrial zone will result in further fragmentation. However, despite this infrastructure, the porcupine population in Ramat Hanadiv remains connected with habitat further inland, through agricultural fields, and thus the overall viability does not change.

Discussion

There is still exchange possible with other populations in the area and there are connections for the porcupine for dispersal.

Hunting may limit the population size, but within Ramat Hanadiv the population is protected and has limited influence. In the farming area this may form a threat, adding pressure on the population.

The density and total population size is difficult to estimate. However, the modelling of the habitat appears satisfactory. Considering the ecological knowledge of the species and the spatial data, the modelling is considered reasonable.

Table 9

LARCH analysis results for the Indian crested porcupine. Population assessment and network viability assessment

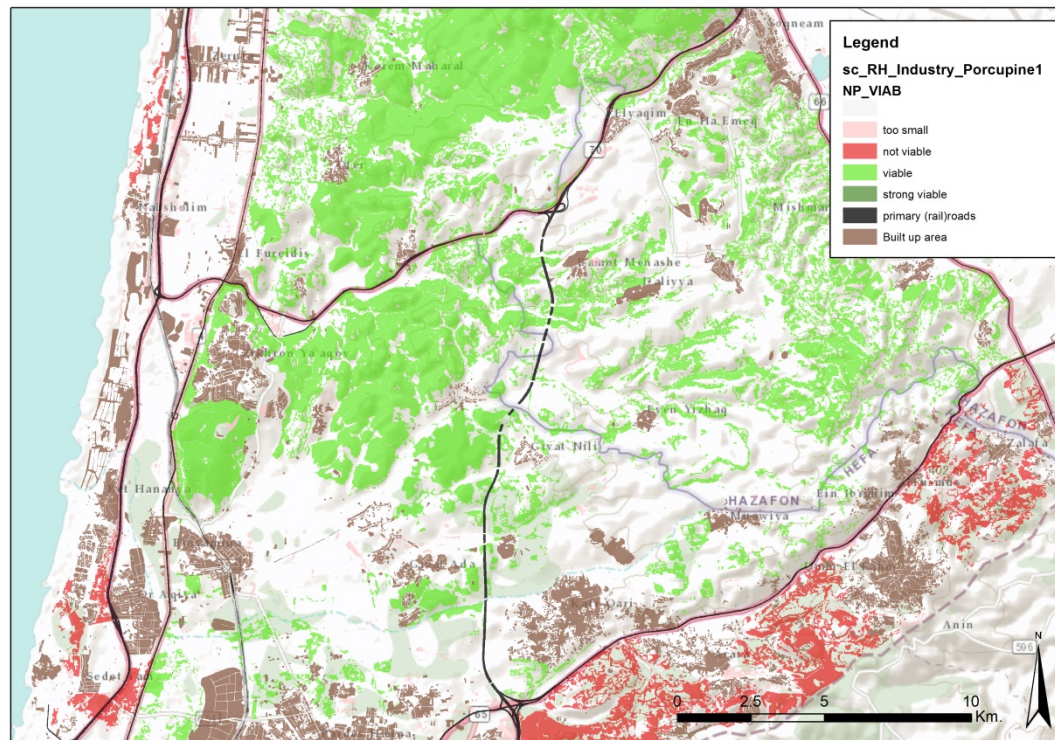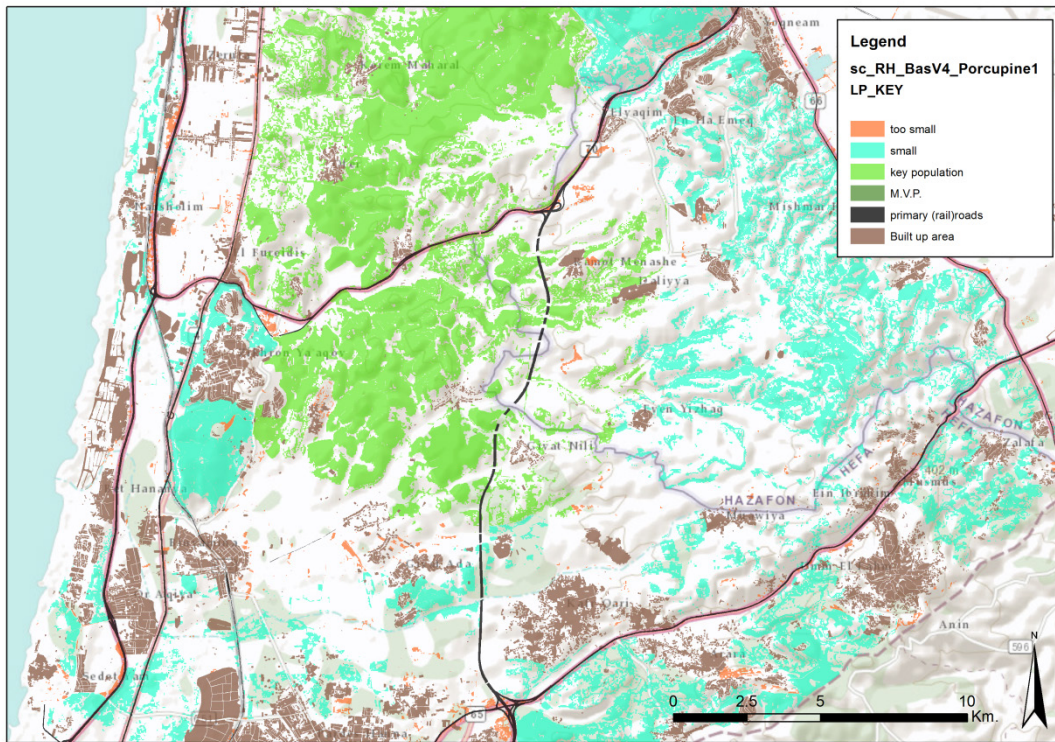| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' RH	RH isolated as an island
Crested porcupine	small	small	viable	viable	not viable

Figure 11

LARCH model results for the Indian crested porcupine. Map above shows the size of the local populations for the current situation. Map below shows the viability of the metapopulation if the industrial zone is developed.

Yellow-necked mouse

Populations

The Yellow-necked mouse is (with the Chukar) the only species which forms a minimum viable population. In the case of the Yellow-necked mouse this is due to the high population density.

Viability of the Network

Currently, and in the scenario situation, the population of the Yellow-necked mouse in Ramat Hanadiv forms a very viable network, even in the case of Ramat Hanadiv alone. The industrial zone has limited impact on this species.

Discussion

The Yellow-necked mouse is not affected by the scenario. There may be local impact by road and industry development, but not on the population level. Therefore, this species is not so indicative for assessing the ecological network at this scale.

The mouse can be viable, due to its high densities. With this map, modelling of micro-habitat is less good and could be improved. However, considering the ecological knowledge of the species and the spatial data, the modelling is considered reliable.

Table 10

LARCH analysis results for Yellow-necked mouse. Population assessment and network viability assessment.

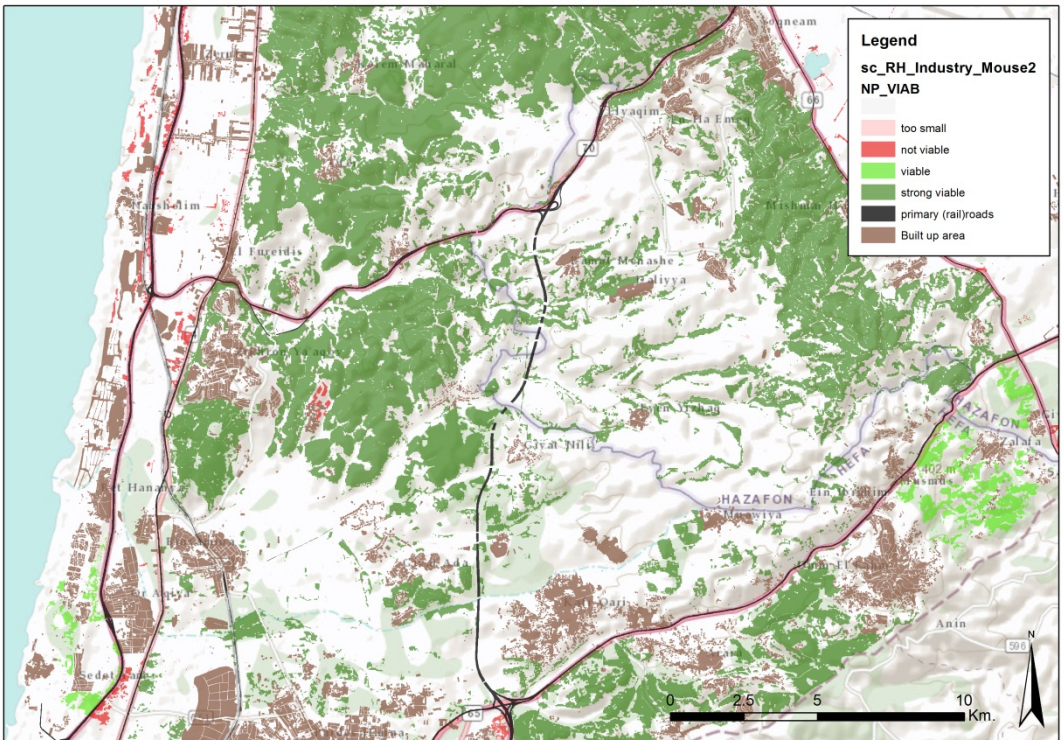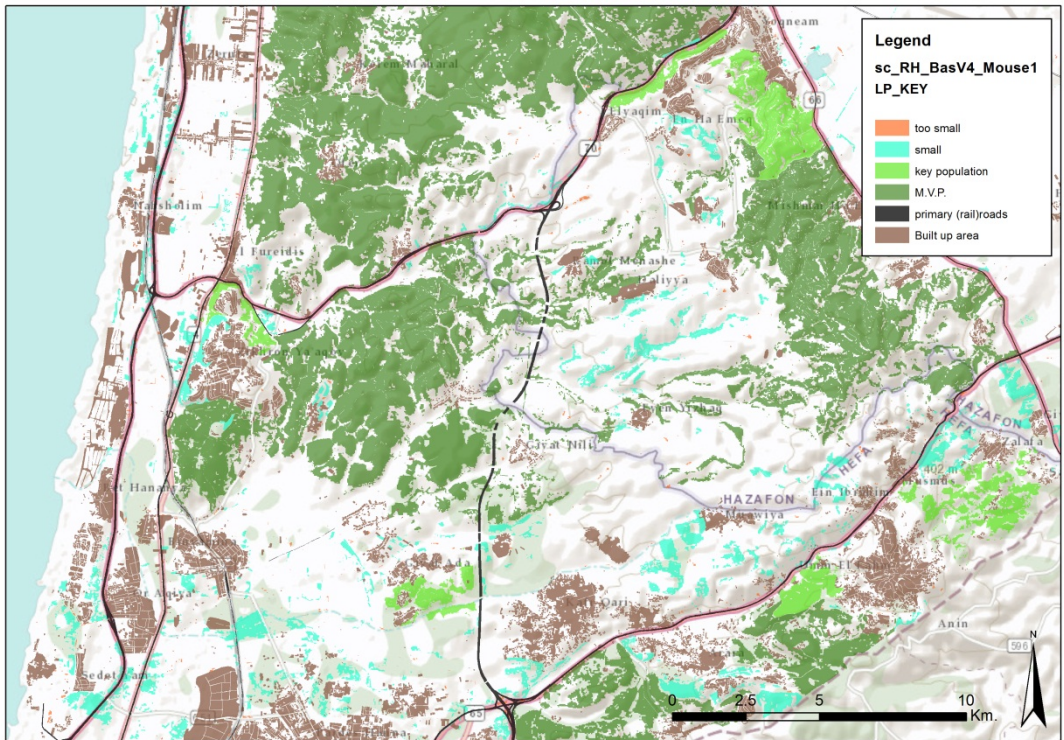| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' Ramat Hanadiv	RH isolated as an island
Yellow-necked mouse	MVP	MVP	strongly viable	strongly viable	very viable

Figure 12

LARCH model results for the Yellow-necked mouse. Map above shows the size of the local populations for the current situation.
Map below shows the viability of the metapopulation if the industrial zone is developed.

3.2.2   Maquis - Shrubland

Mountain gazelle

Populations

Ramat Hanadiv has a small population of gazelles. It is likely simply too small for a key population. However, it is very likely that there is exchange with the larger key population further to the Northeast, in the Alona Forest and the Carmel area. The impact of the scenario on the population size is limited as only some small area is lost.

Viability of the Network

The population of Mountain gazelle at Ramat Hanadiv alone is not viable. The local population of gazelles in Ramat Hanadiv forms part of a larger network of gazelles in the region. It is connected with the larger population inland through agricultural fields, orchards and semi-natural areas. However, because the road and industrial zone will cut off Ramat Hanadiv from the hinterland, the population will not be viable anymore, and no exchange with the larger key population will be possible. As a result, it is probable that the species in the long term will go (locally) extinct and that it will not persist in Ramat Hanadiv.

Discussion

The development of the industrial zone is critical for the long term survival chances of the Mountain gazelle. In the scenario with an upgraded road and an expanded industrial zone, the population of gazelles in Ramat Hanadiv will be isolated from the rest of the region. In the long term, a well-functioning corridor is essential for the survival of the species in Ramat Hanadiv.

Considering the ecological knowledge of the species and the spatial data, the modelling is considered reliable.

Table 11

LARCH analysis results for the Mountain gazelle. Population assessment and network viability assessment.

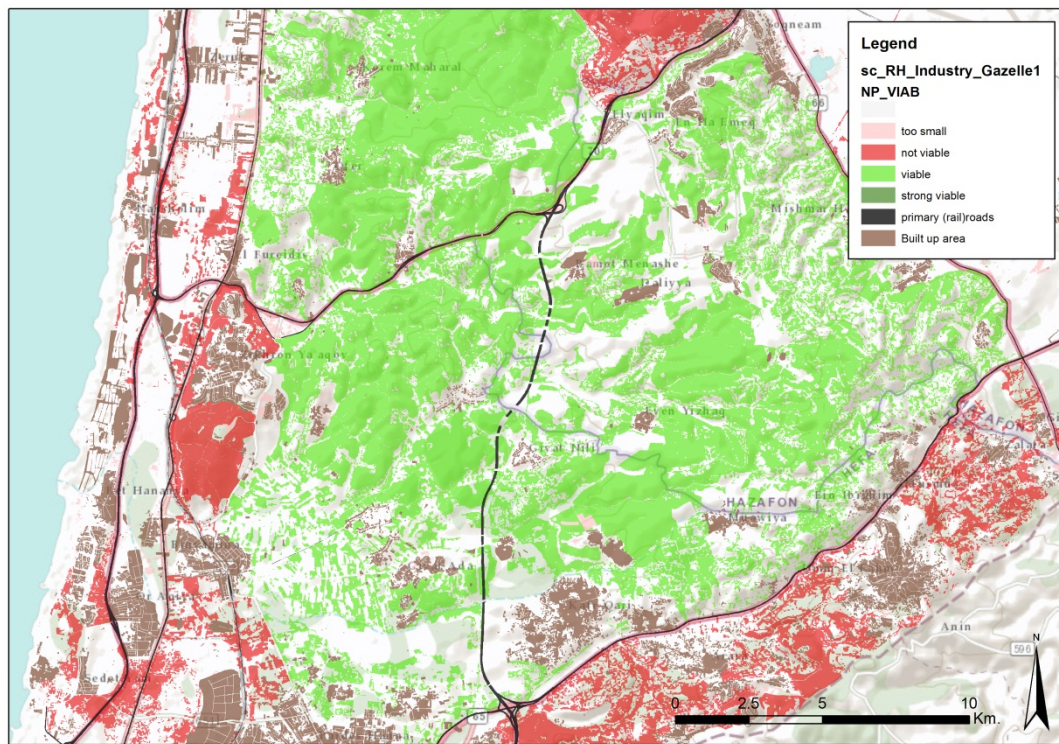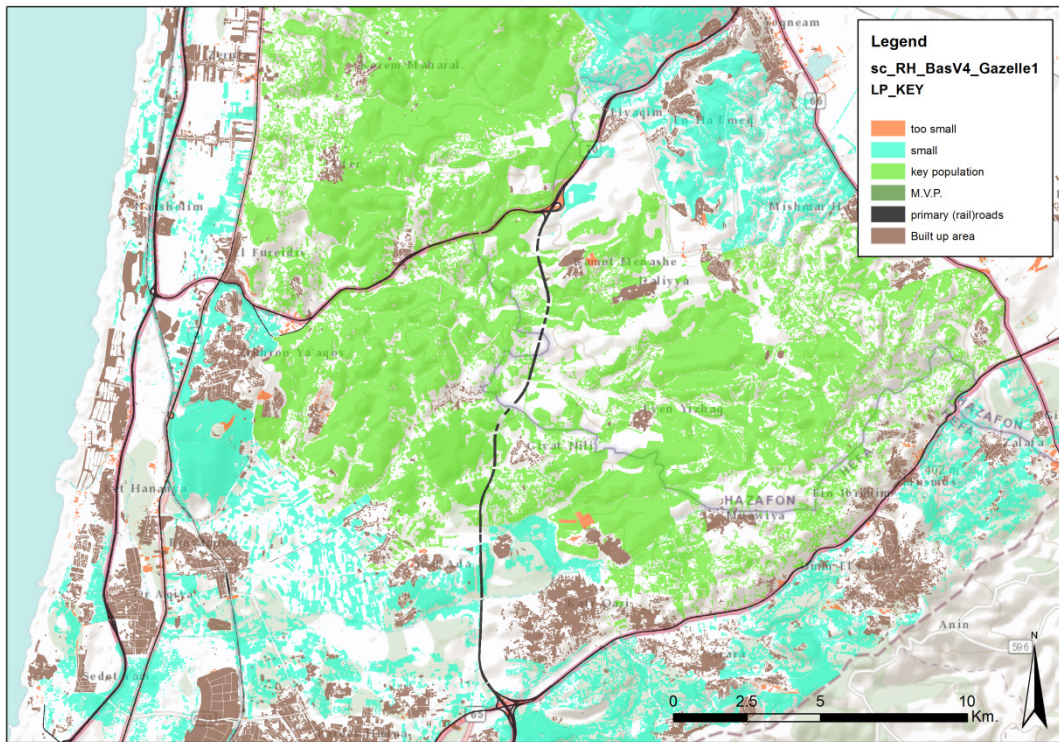| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' RH	RH isolated as an island
Mountain gazelle	small	small	viable	not viable	not viable

Figure 13

LARCH model results for the Mountain gazelle. Map above shows the size of the local populations for the current situation. Map below shows the viability of the metapopulation if the industrial zone is developed.

Armoured glass lizard

Populations

Armoured glass lizards in Ramat Hanadiv potentially form a key population. The population is effectively already isolated, since the species can hardly cross roads. If the industrial zone is realized, almost no change in the size of the local population(s) will occur and it will remain a key population. However, the single potential connection to the East will be lost due to the new industrial zone. The species will migrate exclusively through natural area of open, rocky grassland with shrubs.

Viability of the Network

Currently the local population of Armoured glass lizards in Ramat Hanadiv is potentially a very viable network. The population of Armoured glass lizards is probably not connected to areas outside Ramat Hanadiv.

In the scenario with a new industry zone, the population of Armoured glass lizards in Ramat Hanadiv remains isolated.

Discussion

The glass lizard is vulnerable on all roads and most paths. A wildlife overpass or underpass could improve the situation for this species and restore landscape connectivity.

Reptiles like the Armoured glass lizard are very indicative of species vulnerable for fragmentation. Considering the ecological knowledge of the species and the spatial data, the modelling is considered reasonable for population numbers and density, but still reliable for the species group as a whole.

Table 12

LARCH analysis results for the Armoured glass lizard. Population assessment and network viability assessment

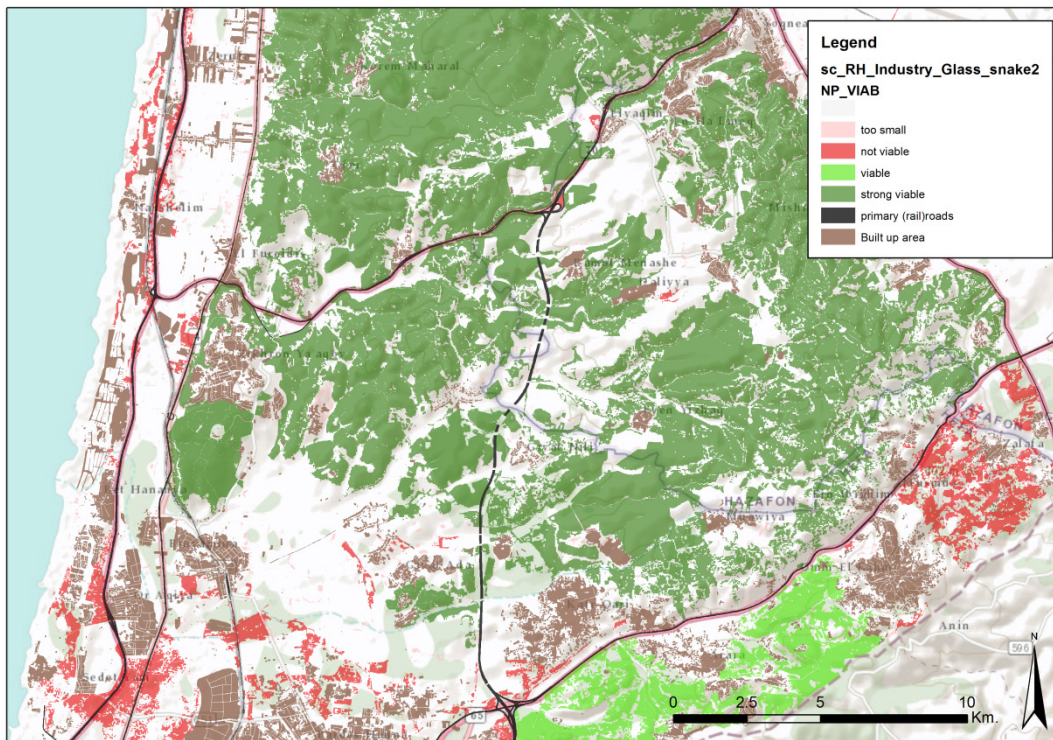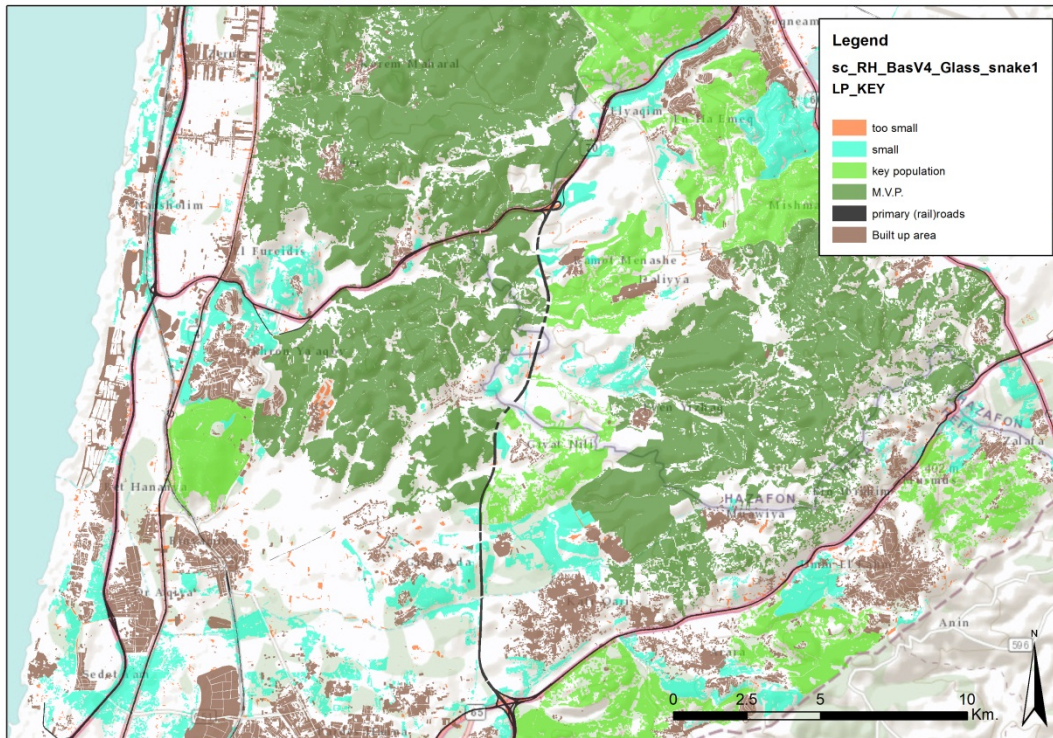| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' RH	RH isolated as an island
Armoured glass lizard	key	key	strongly viable	strongly viable	viable

Figure 14

LARCH model results for the Armoured glass lizard. Map above shows the size of the local populations for the current situation. Map below shows the viability of the metapopulation if the industrial zone is developed.

3.2.3 Grassland and Steppe

False apollo / Eastern festoon

Populations

Ramat Hanadiv forms a key population, based on its local population which includes areas outside the boundaries of Ramat Hanadiv. If the Industry scenario is implemented, the butterfly population of Ramat Hanadiv will change into a small population, since suitable grasslands in the East will be lost.

Viability of the Network

The population of Ramat Hanadiv on its own is not viable, but, as a part of the network it is potentially very viable. However, once grasslands on the Eastern side are lost it is still viable but no longer as strong. The population would become more vulnerable to changes or disasters, which could limit its long term chance of survival.

Discussion

The results shown here are for a butterfly (model) species, using mainly the dense grasslands.
If the industrial zone is developed a threshold is crossed, and it changes from a key population of butterflies into a small population and from strongly viable into viable. In the 'industry scenario' Ramat Hanadiv is still part of a viable population, but landscape connectivity decreases.
False apollo / Eastern festoon are difficult to model since the habitat requirements do not entirely match the detail of the maps. Detailed ecological knowledge is limited, in particular for densities in optimal habitat. Therefore, we should consider these species as 'a grassland butterfly', representative of rough grassland, with a reasonable dispersal capacity and reasonable density. Considering the ecological knowledge of the species and the spatial data, the modelling is considered reasonable for 'grassland butterfly species'.

Table 13

LARCH analysis results for Butterfly species. Population assessment and network viability assessment

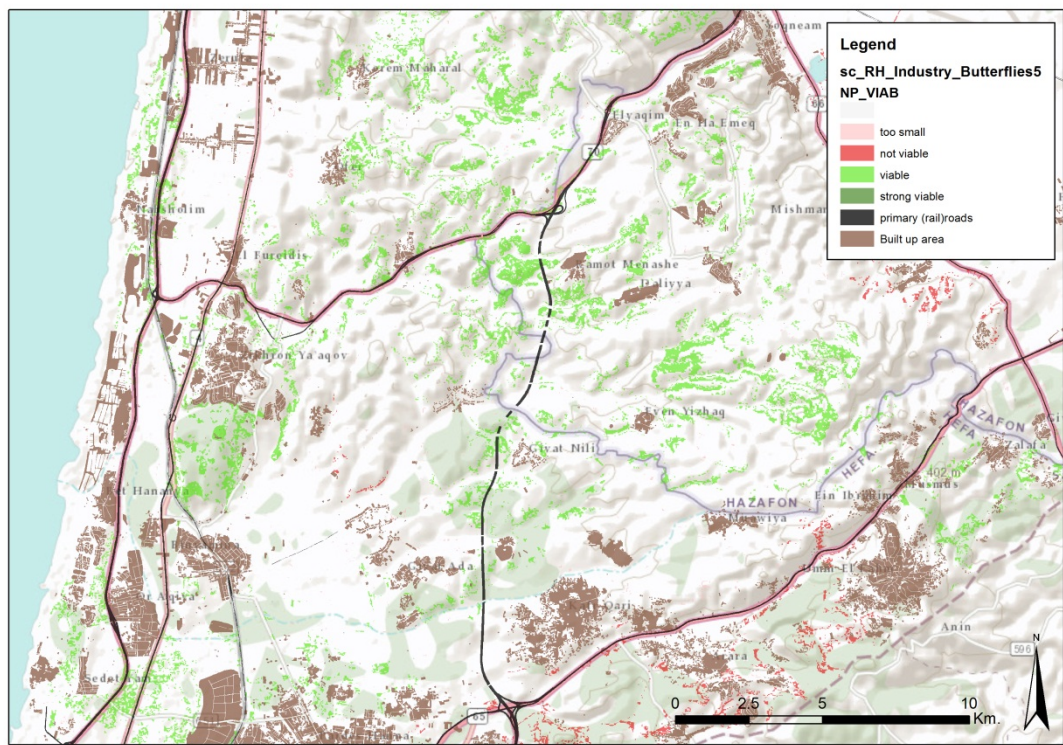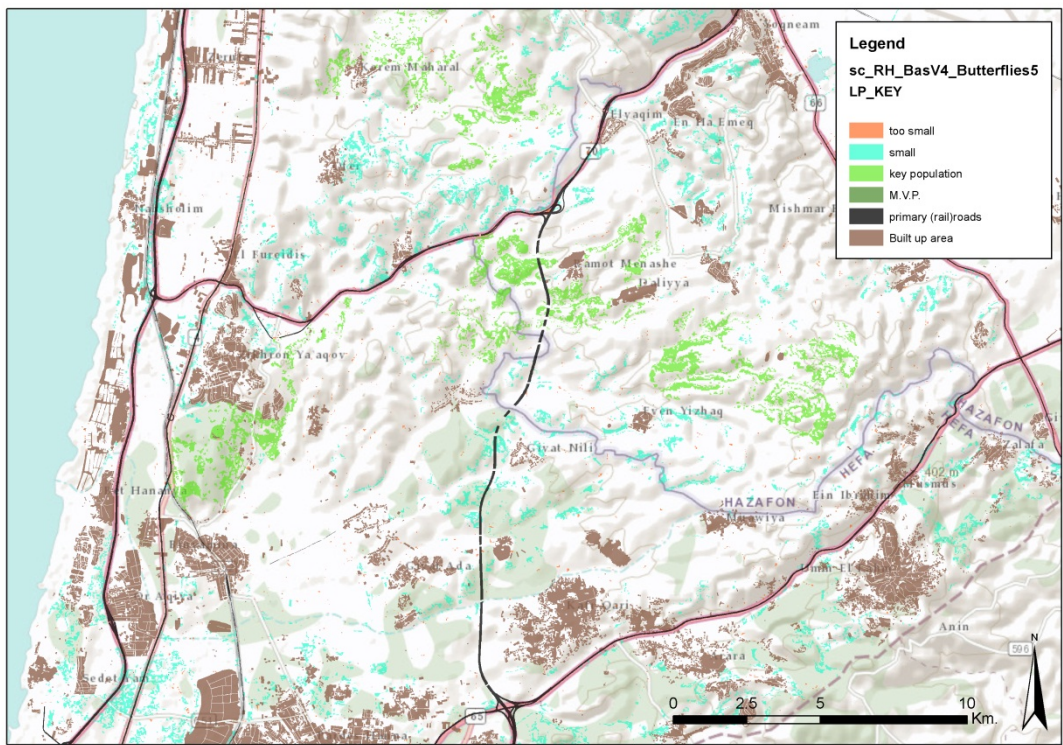| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' Ramat Hanadiv	RH isolated as an island
False apollo / Eastern festoon	key	small	strongly viable	viable	not viable

Figure 15

LARCH model results for the butterflies. Map above shows the size of the local populations for the current situation. Map below the shows the viability of the metapopulation if the industrial zone is developed.

Chukar partridge

Populations

The Chukar partridge is a mobile species with a large home range. All suitable habitats therefore link up to one minimum viable population. The scenario in which some habitat is lost to industry has limited effect on this mobile species.

Viability of the Network

As a minimum viable population, the population is very viable, both under current conditions and when the scenario is implemented. Since the species has no particular need for corridors, it is hardly affected by relatively small local developments such as the industrial zone.

Discussion

A mobile species like the Chukar is hardly affected by the intended industrial development. In fact, in range it does not match the scale of the area analysed.

Considering the ecological knowledge of the species and the spatial data, the modelling is considered reliable.

Table 14

LARCH analysis results for the Chukar partridge. Population assessment and network viability assessment.

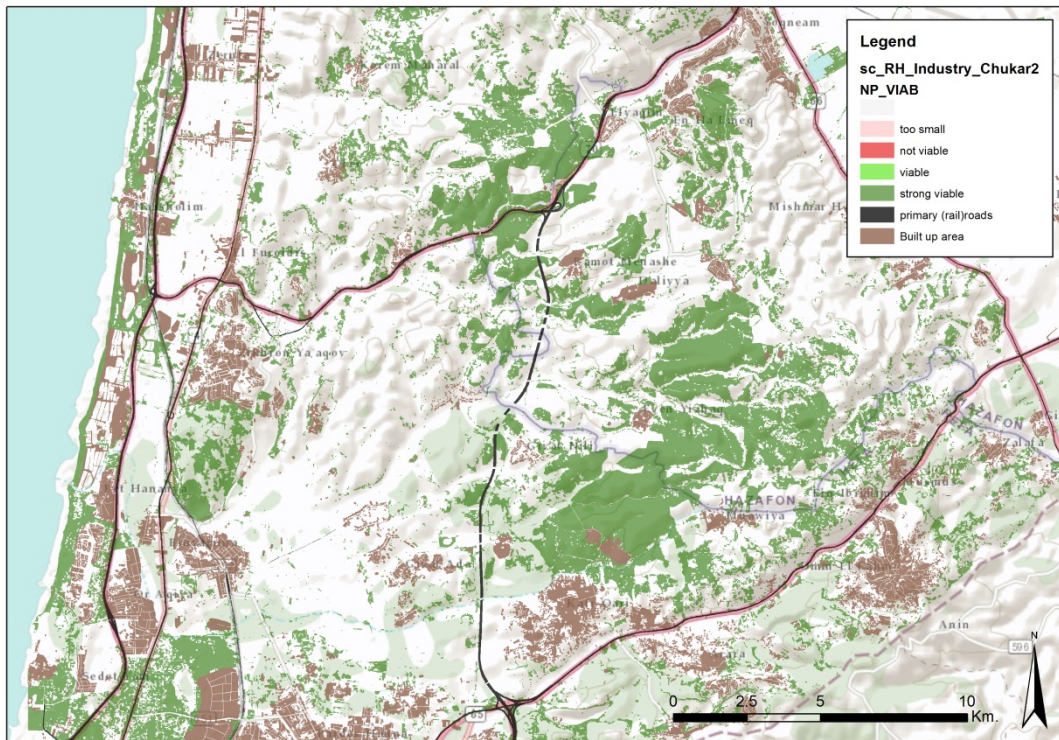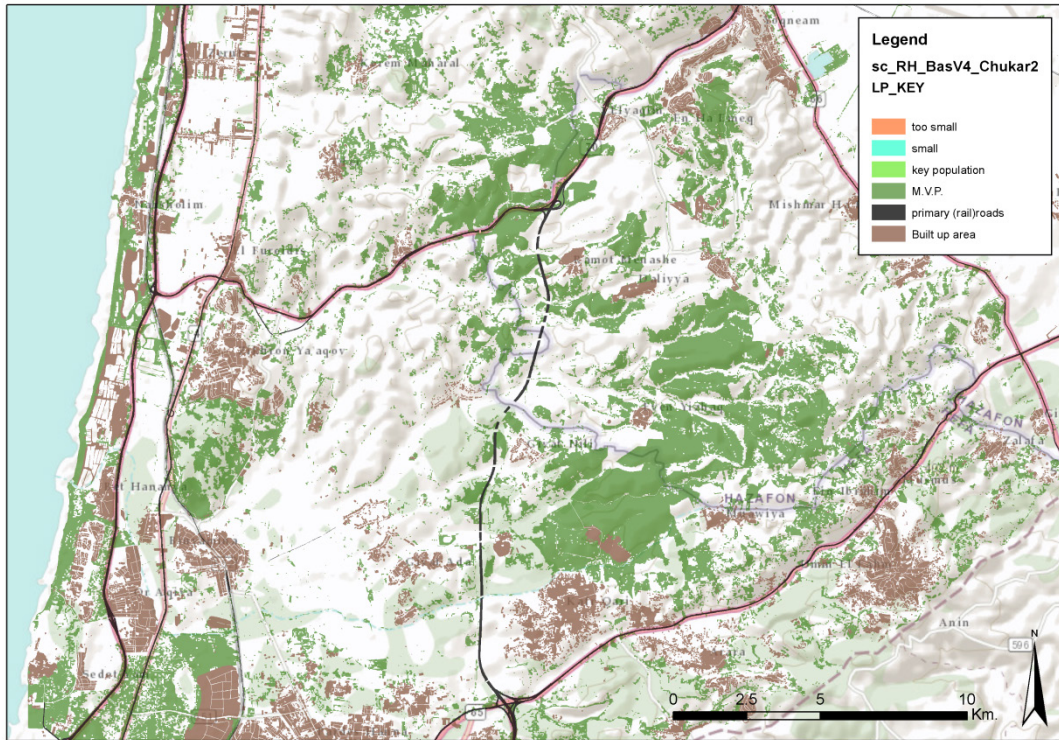| Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' Ramat Hanadiv	RH isolated as an island
Chukar partridge	MVP	MVP	strongly viable	strongly viable	viable

Figure 16

LARCH model results for the Yellow-necked mouse. Map above shows the size of the local populations for the current situation. Map below shows the viability of the metapopulation if the industrial zone is developed.

3.3 Landscape Connectivity Results (LARCH-SCAN)

The landscape connectivity analysis has been done solely for the Roe deer since:

- It is one of the three species showing a negative effect in the viability analysis (with Mountain gazelle and the butterflies).
- The species has a good dispersal capacity, but is also showing strong negative effects towards barriers.
- The calculations in the LARCH SCAN are very time consuming.

The connectivity results for the Roe deer can be seen as representative for the other species. Of course, it may differ slightly depending on their habitat use and dispersal capacity (e.g., the use of agricultural areas). The parameters used for the analysis are equal to the parameters used for the viability analysis. In addition, all land-use classes have been given a relative resistance value (e.g., the resistance of agricultural areas has been set twice as high as natural vegetation and highway crossings have a very high resistance).

No other corridors have been designed in this model exercise to establish what the effect of the complete isolation of Ramat Hanadiv could mean for the species. Other options like the inclusion of additional corridors next to the river bed (e.g. Taninim River) have not been modelled, but if detailed dimensions are available, additional scenarios like these could be calculated by the model as well.

In the scenario with a new industrial zone, the connectivity between Ramat Hanadiv and the surrounding nature areas is becoming too weak for a positive exchange between networks. The barrier-effect of major roads and the industrial zone decreases the modelled landscape connectivity around Ramat Hanadiv. The longer distance through farmland will limit the effective exchange between wildlife populations. The agricultural areas still provide a weak link to the Eastern natural areas (Figure 17A).

Figure 17B shows the same calculation with a corridor of 50 metres in width. Some improvement as a result of the corridor is clearly visible (compare Map A and B), but it also shows that the modelled connectivity is probably too low to create a good and functional connection. A much wider corridor with a width of ~150 metres creates a strong connection to and from the Eastern natural areas (compare Map 17B and 17C). The 150 metres is intended as an example, to show the impact of corridor width, and is not per se a proposed measure for Ramat Hanadiv. The optimal solution will be assessed in Phase 2 of the project.
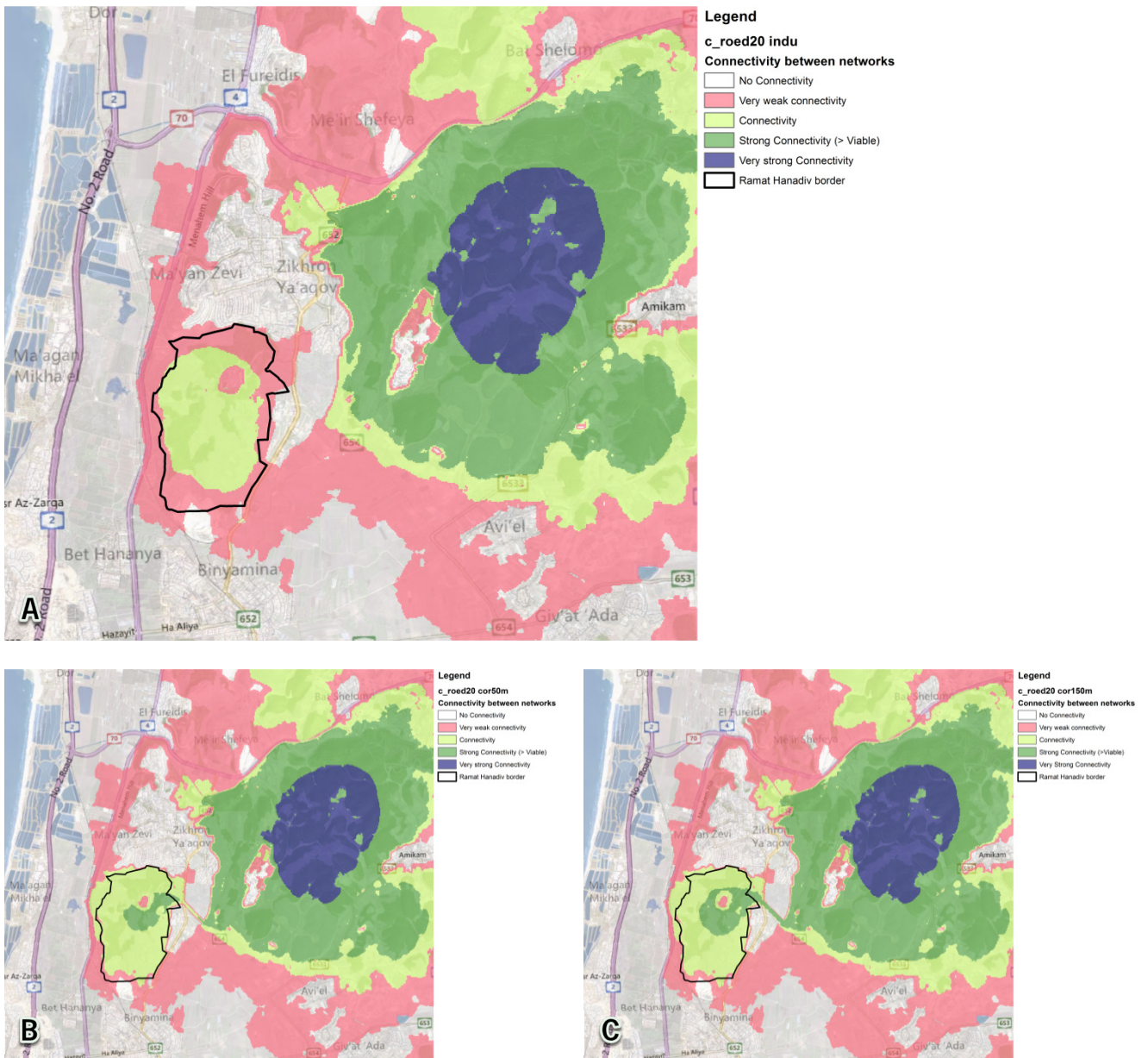
Figure 17
Landscape connectivity for Ramat Hanadiv (black outlined area) with direct surrounding areas for the Roe deer. Grid resolution is 20 m. Map 17A shows the Landscape connectivity without corridors. Map 17B shows a corridor of 50 m wide. Map 17C shows the improved connectivity in the case of a 150 m wide corridor.

3.4   Corridors and Road Crossing

To maintain viable populations and landscapes with rich natural flora and fauna, it is essential that the area is embedded in a wider ecological network. The connecting corridors will ensure sufficient landscape connectivity. This is especially important for less mobile species, i.e., in the case of relatively small areas in fragmented (often urbanised) situations, like Ramat Hanadiv. The landscape connectivity analysis shows that best connectivity is northeast of Ramat Hanadiv. However, it is important that all corridors for various ecosystems (terrestrial and aquatic corridors) are protected and restored as much as possible.

The best measure to improve the landscape connectivity will be to ensure that corridors eastward are maintained. These are true 'lifelines' for Ramat Hanadiv. The best location for the corridor would be northeast of Ramat Hanadiv, through the industrial zone (Figure 18, corridor A1). The width of the planned corridor (50 metres, according to the planning map) is insufficient for the important species. The landscape connectivity analysis shows that the corridor should be at least 100-150 metres wide.

In addition, the corridor assumes that a crossing for the main road, that is both safe and functional for the selected species, is developed that. The effectiveness of a wildlife crossing depends very much on the species for which it is intended and the specific design of the crossing (Grift et al. 2013). This should still be addressed in greater detail, as is planned for the next phase.

A potential corridor exists in regional plans along the Taninim River (Figure 18 corridor B), but is not yet worked out in any detail. This corridor would require further analysis and likely a significantly greater investment of resources, considering the length of the corridor and the current land-use along the river. A much wider corridor would be necessary if the length of the corridor increases significantly, since species will be deterred if they have to pass through corridors over longer distances. Therefore, this has not been assessed in this study.

Additional measures which must be considered in the design phase are the fences to stop wildlife from entering the roads, and traffic regulating systems to avoid car collisions. Also, the vegetation should provide sufficient cover for animals so they can make effective use of corridors. Animals can be guided towards the entrance of a road crossing through effective use of the vegetation and morphology of the terrain.

The corridors considered and studied are terrestrial corridors, aimed for species from forests or grasslands. Aquatic or riverine species have not been taken into account. The functionality of such an aquatic corridor has not been assessed, but the river is important as well, for connecting wetland areas situated west of Ramat Hanadiv, along the coast near Ma'agan Michael (Figure 18 corridor C). In particular, if the quarry south of Ramat Hanadiv is developed and restored, it could form an important wetland area and stepping stone for aquatic species. At the same time, ponds in the quarry would provide additional water for wildlife populations.
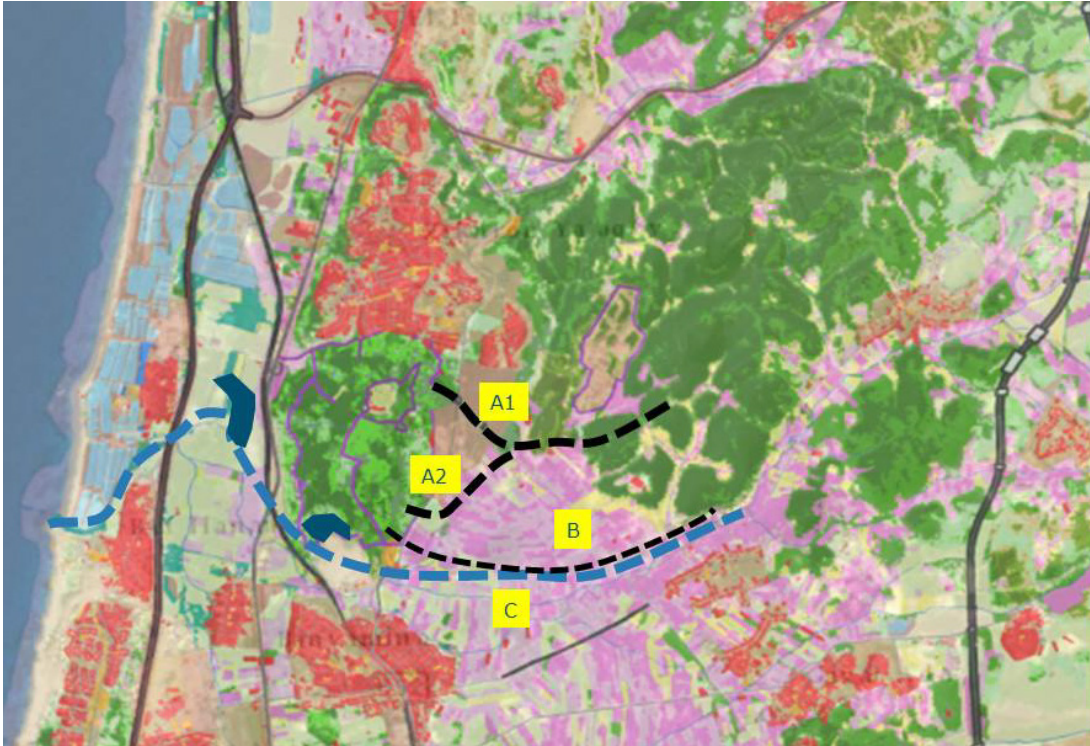
Figure 18

Possible locations of corridors: a terrestrial corridor through the industrial zones (A1- discussed and analysed option), South of industrial site (A2), terrestrial corridor along the Taninim River (B), a wetland corridor along the Taninim River (C).

4   Discussion

4.1   General Results

The modelling results seem fairly satisfactory, considering the modelled and expected population numbers. The base map used for the modelling, has sufficient detail for most species.

Most of the selected species seem suitable to assess landscape connectivity. The Yellow-necked mouse is not particularly indicative at this scale level. The Chukar is rather mobile and also not so indicative at this level. Grassland ecosystems (butterflies and Chukar) are therefore less well covered, nor is this the most representative habitat for Ramat Hanadiv.

In general, we see that most species cannot persist (are not viable) if Ramat Hanadiv were to be island (Table 15, last column). In fact, only the Yellow-necked mouse, the Armoured glass lizard, and the Chukar would be viable – even without connections to the surrounding natural areas. It should still be noted, that there is a risk for viability of species in light of climate change or environmental disasters like large fires, as occurred at Mount Carmel in 2010. These three species would form a MVP (minimum viable population) or key population.

Table 15
LARCH modelling results for all species, current situation and scenario. The yellow box marks species for which the industry scenario results in population changes.

Species	Local population		Viability of population		
	Current	Scenario	Current - Ramat Hanadiv in region	Scenario 'Industry' Ramat Hanadiv	RH isolated as an island
Roe deer	small	small	viable	not viable	not viable
Badger	small	small	viable	viable	not viable
Fox	small	small	viable	viable	not viable
Porcupine	small	small	viable	viable	not viable
Yellow-necked mouse	MVP	MVP	strongly viable	strongly viable	very viable
Mountain gazelle	small	small	viable	not viable	not viable
Armoured glass lizard	key	key	strongly viable	strongly viable	viable
False apollo / Eastern festoon	key	small	strongly viable	viable	not viable
Chukar partridge	MVP	MVP	strongly viable	strongly viable	viable

We see that all other species in Ramat Hanadiv would form small populations, or sometimes key populations or MVPs (Table 15 column 1 and 2). Provided that Ramat Hanadiv is part of the wider region, the populations are viable (column 3).

However, if we consider the scenario in which the industrial zone is developed as planned and the road is upgraded, the situation alters. The population of Roe deer and Mountain gazelle would no longer be viable. This means, that in the long term, these species will become locally extinct and they will not exist in Ramat Hanadiv anymore. Also, the butterfly population would decline, although it would still be viable.

We see no very drastic changes for the other species as a result of the scenario and no huge collapse of populations. This is because the migration of species through farmland cannot be excluded or may even be likely (considering all the negative impact with regard to crop damage and car collisions).
In the agricultural areas, species are much more vulnerable because of exposure, less cover, and the risk of being shot. Animals crossing the road may be killed as a result of car collisions which not only result in property damage, but also in loss for potential wildlife populations, which can be critical for a species. Species foraging in fields are exposed to chemicals and pesticides, which may also be harmful to the species. But, the greatest conflict may be with surrounding farmers who face crop damage. A well-functioning corridor which leads animals to natural areas further east would decrease the conflicts as animals could find better forage in natural areas, particularly if water is also available.

The LARCH model shows the relative importance of the natural areas. Due to the size, it may seem that Ramat Hanadiv depends on the larger areas further to the North and East. However, considering that the area is well managed and is optimally protected from hunting or fires, it is probable that Ramat Hanadiv is an important source area for regional conservation. This is also clear from the high species diversity of Ramat Hanadiv in a regional context. The efforts of the park are therefore important for maintaining regional biodiversity.

4.2   Need for Corridors for Ramat Hanadiv

The modelling clearly shows that the landscape connectivity may be the 'tipping point' for most of the modelled species, particularly the vulnerable Roe deer and Mountain gazelle which depend on the connection with other natural areas. The affected species are representative for medium and large mammals, reptiles, and less mobile invertebrates.

The Taninim River may function as a corridor for some species. The actual value of the river corridor is low, since the surrounding area is mostly used for intensive farming. The landscape resistance of farmland is much higher than areas with natural vegetation. The total length of this corridor, some five kilometres from Ramat Hanadiv to the Alona Forest, just north of the village of Avi'el, would require many landscaping measures to ensure that it would function as a corridor. According to planning regulations from the river authorities, 25 metres along the river should be protected. If that would in fact happen, the value would increase for wildlife and the Taninim River could form a more effective corridor.

The assessment of landscape connectivity shows the clear impact of the corridors, and also the effect of the width of the corridor. A relatively narrow corridor of 50 metres wide shows a barrier-effect which decreases the modelled connectivity around Ramat Hanadiv.
A corridor with a width of some 150 metres creates a strong connection to and from the Eastern nature areas. This clearly has a positive effect on the landscape connectivity so; the corridor has a positive effect on landscape connectivity. However, the width of a corridor should be defined based on local conditions and possibilities for relevant species. This should be addressed in the next phase of the project.

Analysis shows that few species are viable in Ramat Hanadiv alone. Almost all require some exchange with surrounding populations. The exchange with surrounding areas is therefore essential for biodiversity in Ramat Hanadiv. In particular, the large mammal species are vulnerable to fragmentation i.e., the Roe deer, and Mountain gazelle. Reptiles and a vulnerable species like butterflies will decrease as a result of the analysed

scenario. Those species may disappear in the long term. This underlines the importance of the establishment and protection of natural corridors for wildlife species and of connecting Ramat Hanadiv with areas like the Alona Forest. The corridors are truly lifelines for Ramat Hanadiv and are essential to maintain long-term biodiversity.

Location of the planned corridor and road crossing, view from Ramat Hanadiv towards the east

Egyptian mongoose (Herpestes ichneumon) crossing the road at the location of the proposed corridor, during field visit February 2013.

Warning sign for Mountain gazelle crossing the road

5 Conclusion and Recommendations

- Protect and strengthen corridors

As we detail in this study, further isolation of Ramat Hanadiv will be detrimental for several species. This is even more apparent if we look at additional factors like climate change and autonomous development in the region, and possible decline of habitat quality as a result of further urban pressures etcetera. This all supports the need for a concerted attempt to maintain and strengthen the corridors for Ramat Hanadiv.

The farmland still allows some migration of species at the moment. However, this may change when farming becomes more intensive, when more hothouses are built, or when areas are fenced off. In such cases, corridors become even more important for maintaining biodiversity in Ramat Hanadiv.

- Wildlife overpass or underpass

Important barriers such as the main road between Zichron Ya'akov and Binyamina should be made passable for target species. These can be in the form of wildlife overpasses (ecoducts), culverts, and tunnels. There are good opportunities while in the design phase of the road to plan appropriate overpasses at a relatively low cost.

- Road crossing design

The type of facility to be developed depends on the species for which it is intended. The choice of the structure is at least as important as its technical design and the location. A culvert which is flooded during a rainy season may not function for some species, nor will a culvert which is poorly located for the current wildlife habitat and corridors.

- Location of the corridors

The best location for this corridor seems to be between the industrial zones, where the very small corridor is indicated on the planning map (Figure 18 corridor 1A). The corridor along the Taninim River could be further investigated, but seems less suitable and feasible.

- Green business sites

It is recommended that a plan will be developed for a 'green business site' by the local authorities. A green business site can still facilitate wildlife migration. There is already considerable experience with green business sites, be it in the United States, the Netherlands, or elsewhere. This will require specific measures to make it more environmentally friendly. These include the development of natural vegetation structures (landscaping measures), combining the corridor with a wadi, creating additional drainage areas like ponds, avoiding large concrete areas, and promoting specific industries. As a green business site is very innovative and is likely new to Israel, Ramat Hanadiv, with its experience and professionalism, could serve as an important resource and could have a leading role in its development.

- Stakeholder approach

The development of the connections across the road eastward does require good communication with, and support from, stakeholders like spatial planners, politicians, land owners, and zone developers. Multifunctional land-use is a key factor in this development and a good planning process can result in win-win situations. It is therefore recommended, that in the project planning phase, close cooperation is established with stakeholders, to give them a role in the area development process.

- Restoration and development of the quarry

Binyamina's quarry, adjacent to Ramat Hanadiv, has much potential to support regional biodiversity. The analysis shows that Ramat Hanadiv is (too) small for many species and that the quarry which exceeds some 100 ha can add important habitat which could improve overall viability of wildlife populations for many species. Currently there are some perennial ponds that with proper landscaping could support many more birds, mammals, amphibians, and invertebrate species.

In addition, the restoration of the quarry will be invaluable for both education and tourism.

- Wetland corridors

At this stage, no particular species for wetland habitats were analysed. Nevertheless, we understand the ecological need for this habitat and realize the potential for its depletion in Israel. In the event of further development of wetlands in the coastal plain, there are good opportunities to link an aquatic corridor with ponds that can be developed in the quarry, and further along the Taninim River. It is therefore recommended, to explore more opportunities for wetland development and general aquatic ecosystems in the region.

- Corridors are Essential for the perpetuation of wildlife in Ramat Hanadiv

Analysis shows that almost no species are viable in Ramat Hanadiv alone and that almost all require some exchange with surrounding populations. The exchange with neighbouring areas is therefore essential for biodiversity in Ramat Hanadiv and its surroundings. This underlines the importance of the establishment and protection of natural corridors for wildlife species that will connect Ramat Hanadiv with other natural areas.

Field visit to assess possible corridor locations (February 2013)

Annex 1 The LARCH model

To assess and evaluate the functioning and viability of the ecological network of a bird species, the landscape ecological model LARCH (Landscape ecological Analysis and Rules for the Configuration of Habitat, developed at Alterra) can be used. LARCH is designed as an expert system, used for scenario analysis and policy evaluation. The model has been fully described elsewhere (Bruinderink et al. 2003; Van der Sluis and Chardon 2001; Van der Sluis et al. 2007 ; Verboom et al. 2001; Verboom and Pouwels 2004). The principles of LARCH are simple: the size of a habitat population determines the potential number of individuals of a specific species it can contain. The distance to neighbouring patches determines whether it belongs to a network. The size of the network determines whether it can contain a viable population. If so, the habitat network is potentially sustainable for the species. The evaluation of the sustainability of an ecological network is based on total network area, on habitat quality, and on the spatial cohesion of the habitat patches. Different steps in LARCH are illustrated in Figure A.

LARCH provides information on the metapopulation structure and population viability of a species in relation to habitat distribution and carrying capacity (of habitat patches). It assesses spatial cohesion of potential habitat and provides information on the best ecological corridors in the landscape. The LARCH model uses a land-use map or vegetation map as its basis, which describes and represents the habitat of a species. The quality of habitat patches is expressed in classes. In addition to information on the species habitat, the LARCH database contains the spatial characteristics of the species (e.g., dispersal distances, home range, densities, and spatial requirements for sustainable populations). The database with habitat and spatial characteristics is based on extensive literature studies, field studies, and on elaborate population dynamic modelling. In each case, all parameters are checked with (local and national) experts.

The LARCH model uses a set of rules based on metapopulation theory. The output of the model consists of a map which outlines the ecological networks of the species of interest, and visualizes the sustainability of the networks and the spatial coherence of the habitat. Effects of barriers (like roads and urban areas) are included, but these are not relevant for birds or butterflies.
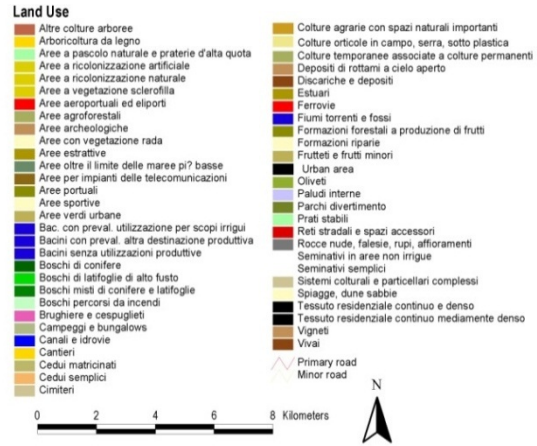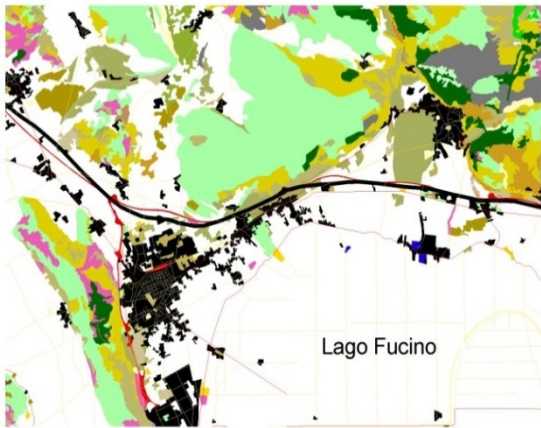
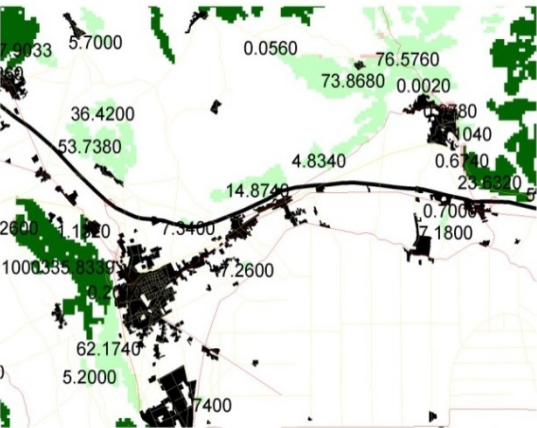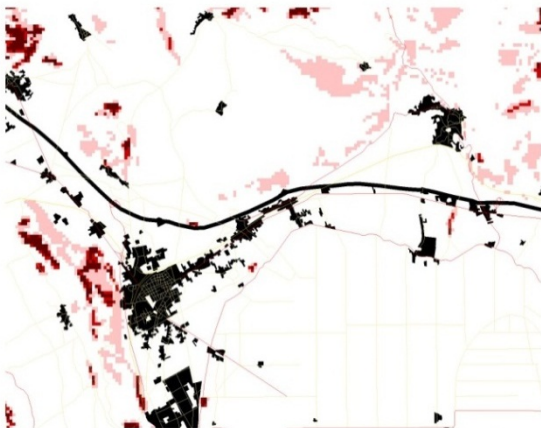Fig. AA: Input for LARCH is the land cover map

Fig. AB: Assessment of carrying capacity

Fig. AC: Identification of local populations and key-patches based on carrying capacity
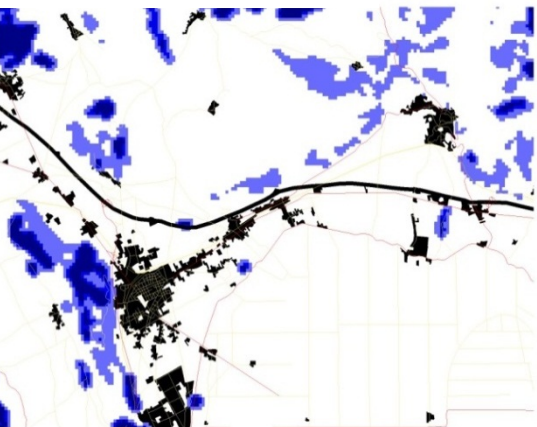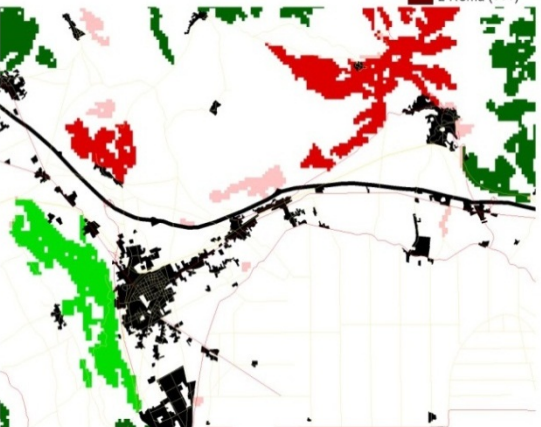

Fig. AD: Identification of network populations and sustainability of network

Fig. AE: LARCH-SCAN, analysis of spatial cohesion

Figure A: *LARCH analysis procedure;* **Fig. AA to AD** *indicates the steps in LARCH to assess the viability of a population network based on the habitat map:* **Fig. AE** *illustrates the spatial cohesion. See text for further explanation of steps.*

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