WILDLIFE PASSAGES AND LAND USE: COORDINATION REQUIRED

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ABSTRACT

Section 18 of Cross-Israel Highway (road no 6) runs through a sensitive landscape of open countryside, mainly agricultural, with several small streams, most of which are dry more than half of the year. A careful planning process led to the construction of 4 long bridges and 2 ecoducts (one tunnel and one cut & cover).

We used a BACI monitoring scheme to assess the function of the ecoducts, with the Mountain Gazelle *(Gazella gazella)* selected as the main target species. Pre-construction monitoring phase was held during 2004-2005 and post-construction monitoring phase (1st stage) was held during 2010-2011. In both phases we used several observation methods and track beds. In the post-construction phase we also used wildlife cameras. The main attention was given to the 150m long cut & cover ecoduct. Human use of the area surrounding the road was also recorded.

A variety of species used this ecoduct, some more frequently, and some rarely. Gazelles were recorded a few times. Gazelle usage of the area surrounding the ecoduct seems to have changed before and after construction and operation: in the latter, their main activity was in a more restricted area and the observed group size decreased. Fewer animals from other species were observed in transects in the post-construction phase than before.

Human activity in the area is varied. Several conflicts between human activities and conservation/ connectivity requirements were already noted at the pre-construction phase. Since then, land use in the area surrounding the road has slightly changed, with an increase in cattle and sheep grazing and in agricultural fencing of plots (small orchards and cattle grazing plots), not necessarily related to the road construction. These changes are likely to restrict the ability of the gazelles and of other wildlife to move through the landscape and make full use of the connectivity opportunities incorporated in the road.

Though some improvements to the design of the ecoduct itself are recommended, a coordinated effort of several authorities regarding connectivity and land use is required to help improve the current situation. Such a coordinated effort is beyond the road managers' capabilities and is a major challenge.

INTRODUCTION

Road construction and operation create a barrier in the surrounding landscape and may involve multiple changes to wildlife in the ecosystems involved (e.g. *Forman et al. 2003, Iuell et al. 2003, Fahrig & Rytwinski 2009, Benitez-Lopez et al 2010*). Their impacts are joining other human impacts in the same landscape, forming a complex of stresses on those ecosystems, particularly where human population is relatively dense and the extent of open landscape is shrinking and fragmenting rapidly (*Roedenbeck et al 2007, Achiron-Frumkin 2011*). Quite often, the adoption of sound environmental standards and connectivity solutions by a road company is not necessarily coupled with any complementary management practices or other human activity patterns that may positively affect and enhance the performance of the mitigation measures adopted.

Background

Section 18 of Cross-Israel Highway (road no 6) was opened on July 2009. It runs through Ramat Menashe, a sensitive hilly landscape of open, mainly agricultural countryside in the central-northern part of the country (Figure 1). The landscape is a patchwork of agricultural fields of varying sizes, semi-natural patches of Mediterranean garigue and scattered oak trees (*Quercus ithaburensis*), forestry patches, with several small streams, most of which are dry more than half of the year, and several agricultural settlements (Figure 2).

FIGURE 1 The central part of Israel and the location of the study area, section 18 of road 6 in Ramat Menashe.

FIGURE 2 Ramat Menashe, a hilly landscape made of small patches.

The project was highly controversial and subject to public debate and opposition, largely on environmental issues, during the statutory planning phase. This led to a careful, detailed planning process that engaged the adoption of measures and standards many of which were applied in Israel for the first time. Among others, connectivity requirements were addressed, with the construction of 4 long bridges (ca 250m, 2x240m, 210m long) and 2 ecoducts (a 350m tunnel and a 150m cut & cover, Figure 3), along with many box culverts, fencing (variable mesh size, buried fence) and the implementation of a detailed monitoring program.

FIGURE 3 Two of the long bridges (top), the bridge linked to the cut & cover ecoduct (middle), the tunnel ecoduct (bottom).

At the same time, multiple human activities have been held in this landscape with many stakeholders involved. Moreover, the road is located on the edge of a larger area declared as biosphere reserve in 2011. The varied agricultural activities attract wildlife to additional food sources, which is a possible source for conflicts between wildlife and farmers. Agricultural fencing is therefore relatively common in the study area, forming barriers of varying degrees. A fence (not very well maintained) goes through the hill where the tunnel ecoduct is located and around most sides of this hill. The cut & cover ecoduct was also fenced on both sides with 3 strips of thin barbed wire (lowest wire at ca. 60cm) along most of its width, allowing animal movement yet restricting human entrance. Parts of the stream valleys with the large bridges are fenced for cattle and sheep grazing.

The findings of the monitoring program presented here illustrate the multiple challenges and cooperation required to maintain connectivity in an intensively used landscape.

METHODS

This monitoring program was the first major one conducted for a road project in Israel. We followed general guidelines from the literature (e.g. *Spellerberg 1991, Iuell et al 2003., Clevenger & Hujser 2009*), experimented with the feasibility in the field of several methods and adapted the program accordingly.

Monitoring Scheme

Target Species:
Mountain Gazelle (*Gazella gazelle*), a species of relatively open habitats was selected as the main target species. It is considered sensitive to human disturbances, a target species to conservation efforts, with some of its populations having declined for more than a decade (conservation status defined "vulnerable", *Dolev & Perevolotsky 2002*). It is also subject to illegal hunting. As far as we know it is avoiding box culverts, and at the planning phase we believed it wouldn't cross under bridges, thus possibly being the species most severely affected by the road.

Monitoring Target:
Studying the function and efficiency of the overpasses and underpasses in the project, with a special emphasis on Gazelle use of the cut & cover overpass. No specific quantitative target was set to the rate of use, "how many individuals per time unit is enough" (e.g. *van der Grift 2012, van der Ree 2012*), as these were and still are unknown.

Scale:
Monitoring was held in a restricted and defined study area surrounding the road section, before construction – from March 2004 to March 2005 (=P1) and after construction – from May 2010 to July 2011 (=P2). The main attention was given to the cut & cover ecoduct.

Methodology:
Mitigation measures monitored were the ecoducts and 2 of the long bridges. A Before-After-Control-Impact (BACI) design was adopted. Three pairs of "treatment/impact" points along the proposed route and "control" points some 230-850m away were defined.

Several methods were jointly used to sample and obtain as much data on terrestrial vertebrates' movement in the defined study area:

- Recording tracks – in track beds, on occasional routes and in walking and driven transect routes
- Observations – from a fixed point and survey along a driven transect route through the area
- Photographs – after construction 4 Reconyx motion-triggered cameras (PM75, PC90) were alternately used in several locations, mainly on the cut & cover overpass. Their recordings are also samples in space, as they never covered the whole length, and in time.

Gazelle activity in the study area was mainly recorded while driving through pre-determined transects allowing maximal visibility and by scanning specific patches by foot for tracks and feces. These observations were aimed to learn the spatial usage pattern of the species rather than to assess its population size.

Standards:
The standards adopted are the presence of a species and the frequency of use, if available, pre- and post-construction.

RESULTS

Cut & cover ecoduct (150m wide): This overpass was used by a large variety of species. The terrestrial mammals using it were (by frequency of use): Wild Boar (*Sus scrofa*), Jackal (*Canis aureus*), Red Fox (*Vulpes vulpes*), Porcupine (*Hystrix indica*), Eurasian Badger (*Meles meles*), Egyptian Mongoose (*Herpestes ichneumon*), Eastern Hedgehog (*Erinaceus concolor*), Mountain Gazelle, and Cape Hare (*Lepus capensis*).

It was also used by rodents (including the burrowing Palestine Mole-rat, *Spalax ehrenbergii*), a variety of bird species (including migrants), reptiles and many invertebrates, and evidently was habitat or part of the habitat for quite a few of the smaller species. The passage was used more than once per night by certain species, by the same or by different individuals (individual identity could not be determined in most cases; Table 1).

TABLE1 A monthly activity pattern – example from March 2011. The numbers per species each day denote the number of seemingly independent events.

March 2011	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Wild boar	1	6	4	7	5	5	9	8	3	1	1	2	6	2	4	4	5	4	4	7	1	3	6	6	3	7	4	5	2	3	9
Jackal	4		3	2		1	4	5	3	1			1	1	3	3	7	5	4	2	3			2				1	1		2
Fox								1																							
Porcupine				2							1	1		1	1	1			1			1		1	1						
Gazelle																						1	1								
Mongoose								1								2	1	2												2	2
Hedgehog																			1												
Jay																1								1				1			
Crow															1												1		1		
Chukar																1	1														
human	1		3		1									1		1		2	4		1	2				1	1		1		
man+dog																														1	
cow																													2	1	

Some individuals were seen feeding, playing and engaged in what seemed like territorial activity. In few cases, two cameras recorded different species present simultaneously on the passage, and one of them shows a fox closely behind a porcupine (Figure 4). Few species joined throughout the year.

FIGURE 4 A Red Fox behind a Porcupine using the ecoduct.

Gazelles were recorded on the ecoduct 6 times during this year, two of them on two consecutive days in March. One of them (mid-January) with 3 females and the rest seemed to be a young individual, possibly dispersing, the latter 3 events may have been the same individual (Figure 5).

Human activity was frequently recorded by the cameras: mainly cyclists and hikers but also horse riders with dogs, motor cyclists and training soldiers.

FIGURE 5 Two of the sightings of Mountain Gazelle on the cut & cover ecoduct.

Tunnel: This habitat and its connectivity remained relatively similar between pre-construction (P1) and post-construction (P2) phases. Wild boar, fox and jackal were recorded by cameras. Gazelle feces were recorded on both sides of the hill.

Long bridges: The two bridges sampled had signs of animal activity both near and under the bridge. Badger, porcupine, jackal and fox were recorded by cameras.

Gazelle activity: Gazelles were recorded in both P1 and P2. In both phases most of the sightings were on the western side of the road (Figure 6). During P2, none were seen on transects or in other observations on the eastern side of the road, though local joggers and cyclists reported on occasional sightings there. Gazelles were recorded on both ecoducts but not under the bridges in P2, whereas in P1 few were also recorded in the planned location of the bridges. During P1 certain seasonal changes in the spatial pattern were detected, with more use of the eastern patches in winter and early spring. During P2 gazelle activity was observed on the western side of the road, in a more limited area (Figure 6). Due to the fewer observations in P2 it is difficult to detect such trend, if any.

In P2 there were generally fewer gazelle observations in transects than in P1 (11 vs. 39), the number of individuals in each observation tended to be smaller, the maximal number of individuals observed per survey day tended to be lower (6 vs. 20) and in most survey days in P2 no gazelles were observed at all. Maximal observation duration tended to be shorter in P2 than in P1 (30 min., 20 min. vs. 115 min., 40 min.). In both phases gazelles were seen responding to disturbances: to humans, to dogs and to nearby cattle.

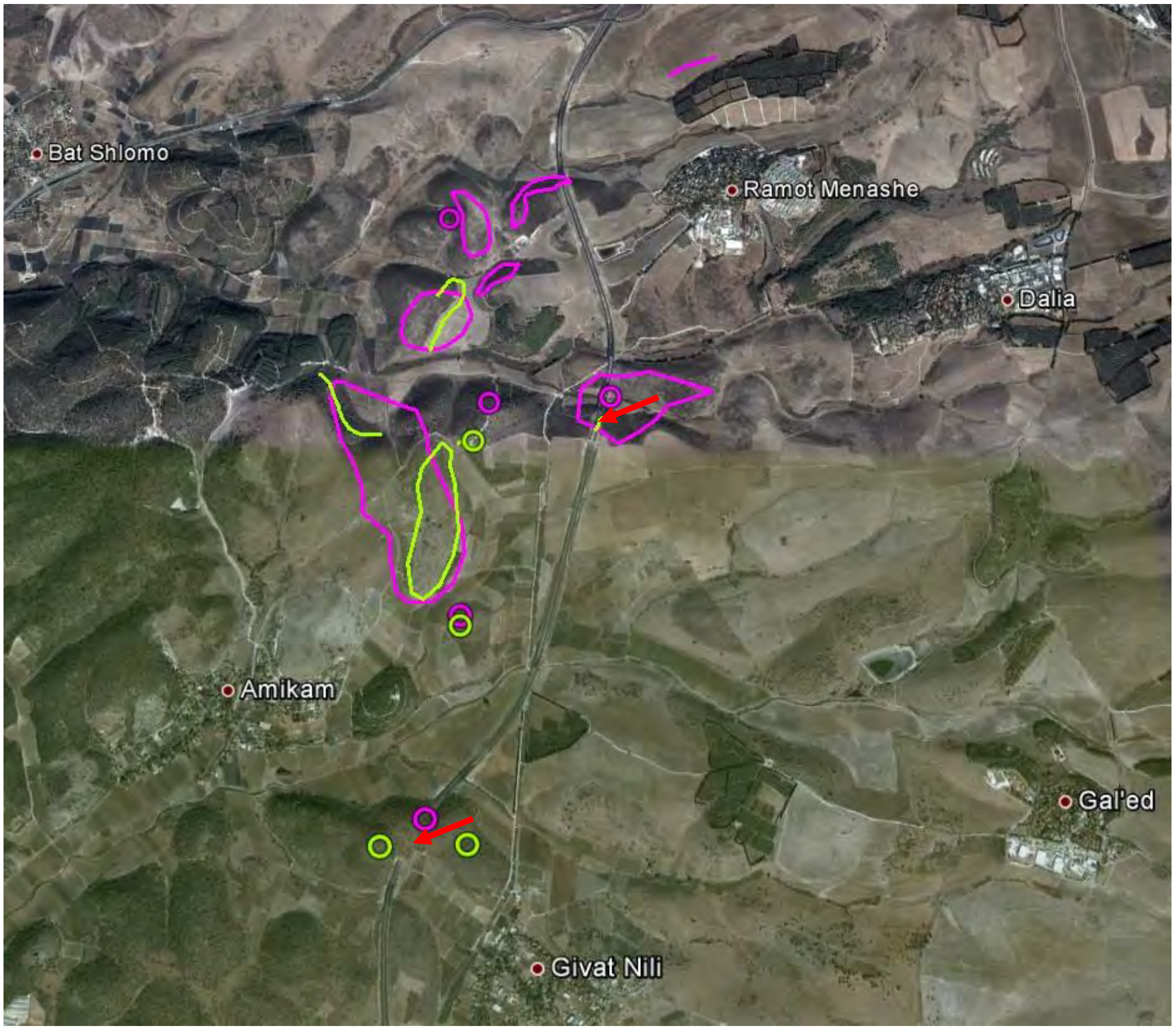

FIGURE 6 Location of gazelle records in P1 (2004-2005, in pink) and in P2 (2010-2011, in light green). Lines and polygons represent areas where animals were seen, circles represent points where feces and footprints were found. Red arrows mark the locations of the ecoducts.

Human activity:
Human activity in the area is varied in its extent, timing, duration and intensity, and affects animal movement, particularly gazelle activity. Human activities include agricultural practices (day and occasional night, also affecting spatial and temporal changes in food supply), passage of vehicles (mainly agricultural), pastoral practices (fenced cattle plots, ranchers moving and treating herds, goats and sheep walking and grazing with shepherds and dogs and in fenced plots), military training activity, varied leisure activity (also at dawn, dusk and at night time, peaking in weekends), illegal hunting and gathering, unaccompanied dog and domestic cat activity.

Agricultural fencing, aimed at both wildlife and human intruders, is a major issue as it introduces additional barriers which disturb animal movement and may limit overpass and underpass accessibility. Most of it is permanent fencing, with just few temporary fences (Figure 7). Between P1 and P2 more fences were installed, old fences were mended and wire density increased, possibly also due to a change in the policy of the ministry of agriculture and increased fencing subsidies for farmers. Figure 8 shows most of the fencing encountered during P2 alongside with the locations of gazelle sightings. Though some of the fences are not complete barriers, they may impede, disturb and reduce survival chances of at least some individuals of the larger species.

FIGURE 7 Few of the fencing types in the study area. Temporary fencing is shown at the bottom.

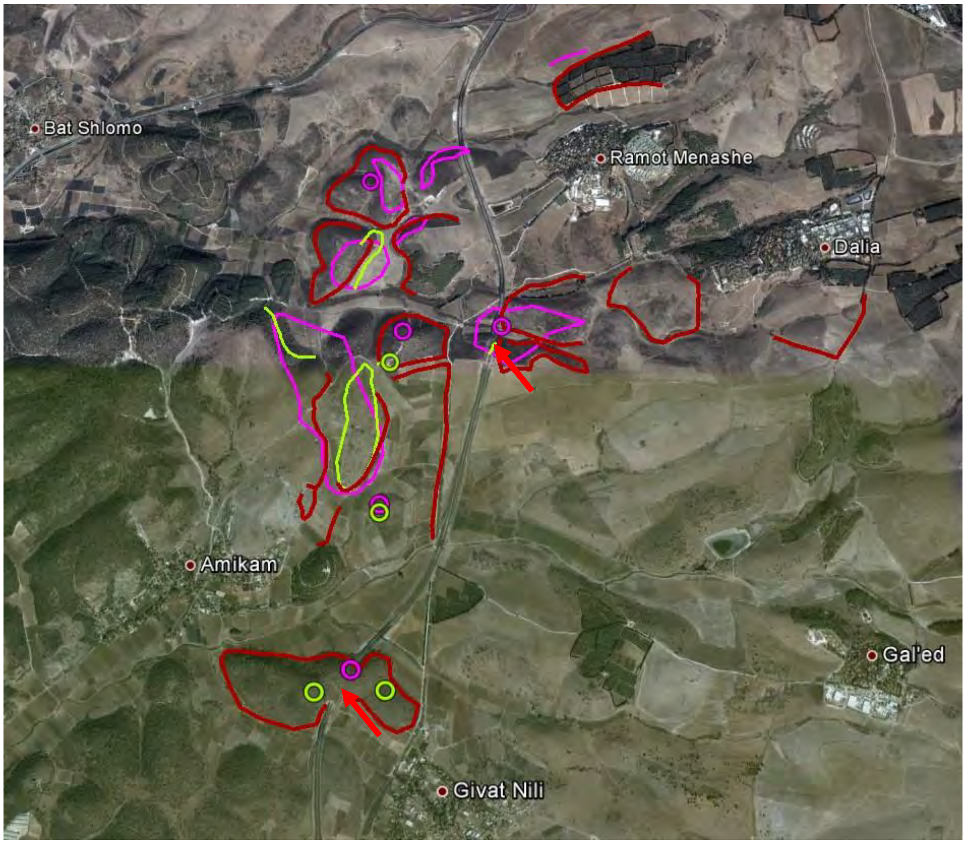

FIGURE 8 Fencing and gazelle observations: Location of gazelle records in P1 (2004-2005, in pink) and in P2 (2010-2011, in light green); lines and polygons represent areas where animals were seen, circles represent points where feces and footprints were found. Dark red lines represent most of the fencing in P2. Red arrows mark the locations of the ecoducts.

Before-After comparison: A descriptive presence-absence comparison of before-after-control-impact shows a similarity in the species recorded between impact and control, both in the cut & cover and near as well as under the bridges (Table 2; standardizing the BACI track bed results was not possible due to technical problems and changes that emerged during fieldwork). The records show large similarity between impact and control points, before and after construction, with the exception of few wild Felidae records in P1 not recorded at all in P2 and hare not recorded in P1, with very few records in P2.

Generally, a variety of wildlife were recorded in track beds and observed. Wildlife direct observations in the surrounding area were fewer in P2 than in P1, with less fox activity and more wild boar activity recorded in P2. There was also random evidence of small animals using few culverts under the road, yet data on this was not recorded systematically.

TABLE 2 A presence-absence comparison of tracks in track beds before and after construction. Background color distinguishes each pair of impact-control points. (In parentheses: species not recorded in tracks, yet evidence on presence – by photo or direct observation).

Tracks	Before						After					
	C&C	control	D Bridge	control	M Bridge	control	C&C	control	D Bridge	control	M Bridge	control
wild boar	+			+		+	+					+
jackal		+		+		+	+	+	+	+	+	+
fox	+	+		+		+	+	+	+	+	+	+
porcupine	+			+			+	+	+	+	+	+
hedgehog						+	+	+	+	+		+
bird	+	+		+		+	+	+	+	+	+	+
hare							+		+			
rodent		+					+	+	+		+	+
badger	+	+		+		+	(+)		(+)	(+)	(+)	(+)
gazelle	(+)	?					+					
(mongoose)				(+)		(+)	(+)				(+)	
wild Felidae		+		+		+						
man	+	+		+		+	+	+	+	+	+	+
dog	+	+		+			+					
sheep	+					+						+
cattle							(+)					+
horse	+			+			+					
bike							+	+		+		
vehicle	+	+		+		+	+	+	+	+	+	+

DISCUSSION

Monitoring results indicate that:

- Mitigation measures are functioning, with animal movement on ecoducts and under the bridges.
- Ecoducts are used by a variety of mammals, reptiles, birds and invertebrates.
- The species that use the ecoduct most frequently are those considered agricultural pest species (wild boar, porcupine, jackal and fox).
- Post-construction phase direct observations were fewer than in pre-construction. This may indicate a slight shift in species' activity patterns or in their vigilance (most of these species are mainly nocturnal and most camera records on the ecoduct were between dusk and dawn).
- Gazelles are still active in the study area, yet less activity was observed in P2, in a more limited area. Observations tended to be of fewer individuals and smaller group size seen in P2 than in P1.
- Gazelles in P1 were rarely observed on the planned locations for ecoduct and bridges, and even less so eastwards. In P2 gazelles were observed a few times on ecoducts, but not eastwards and not under the bridges. This change may derive from a population decrease, from a permanent shift or a decrease in their local range or from a combination of any of these.
- Varied human activities seem to affect gazelle activity and movement patterns. Between P1 and P2 land uses have slightly changed as well as other human activity patterns**.**

We should bear in mind that passage usage does not indicate whether these passages are efficient enough in allowing ecosystem processes and in maintaining viable populations (*van der Grift et al 2013*).

The lower gazelle activity observed in P2 may not necessarily be related to the road, as a barrier and as a source of other disturbance (sound and light), but may be due to other land use changes and to the multiple threats and stresses gazelles experience deriving from human activities (including the road presence). Lower gazelle activity near the road may reflect a population decline, a more permanent shift in their main activity range westwards to less disturbed open woodlands, or both.

Human activity in the study area is complex and has multiple effects on ecosystem components. Multiple stakeholders and governmental and local authorities are involved (e.g. farmers with different activities and interests, tourists, ministry of agriculture, ministry of environment, nature reserves and parks authority, regional council and local councils, forestry agency and biosphere reserve working group, army units, water management agency). Several conflicts between human activities and conservation/ connectivity requirements were already noted at the pre-construction phase (*Achiron-Frumkin & Frumkin 2007*). Though the road is on the edge of a recently declared biosphere reserve, it seems that hardly any management or planning coordination has been truly achieved so far.

It is important to note that the changes in land uses between the two phases are not necessarily related to road construction: the major changes involve an increase in pastoral activity (more cattle and sheep fenced grazing plots) and in the extent and type of other agricultural fencing (mainly around small orchards). A sheep farm with both extensive fencing and a prominent presence of unrestricted dogs that illegally moved closer to the road may be another major obstacle keeping some wildlife away from the passages. Most types of fences are likely to restrict the ability of gazelles and of other wildlife to move through the landscape, along hillsides and in stream valleys, and make full use of connectivity opportunities incorporated in the road. Furthermore, a water reservoir, which will probably be also fenced, is currently planned nearby.

Though much effort was given to road planning, construction and maintenance, and some improvements to the design of screens and vegetation management on the ecoduct itself are recommended, it is difficult at present to address issues of integrative planning and management of the surrounding landscape and to set and achieve targets in this respect. A coordinated effort of several authorities regarding connectivity and land use is required to help improve the current situation. Such coordination is beyond the road managers' scope, capabilities and authority and is a major challenge. As land in this area is state-owned with long-term planning of land uses, a specially assigned coordinating body could discuss problems with farmers and look for alternative locations and solutions for some of their activities. This is particularly relevant to fencing and to the location of pastoral plots and their management. A coordinating body could also promote a range of actions and educational efforts to reduce human activities and impact in the vicinity of the passages so that conservation targets and connectivity targets can be better met.

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BIOGRAPHICAL SKETCH

Dr. Tamar Achiron-Frumkin is ecologist and environmental advisor. She received her B.Sc. in Biology from Tel Aviv University, and her D.Phil. degree from Oxford University. Her thesis, at the Edward Grey Institute of Field Ornithology, focused on avian ecology during the breeding season. Her work in the last few years is dominated by issues related to habitat connectivity, with projects including: a handbook on habitat fragmentation and connectivity, the local version of COST 341 for the Israel National Road Company (2012); State of Nature in Israel 2010 report for the ILTER (2011); team member as ecological advisor on animal passages and connectivity for the major road companies (2004-2013).

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