CENTRO STUDI PER LE RETI ECOLOGICHE

MONTE GENZANA ALTO GIZIO
Riserva Naturale Regionale

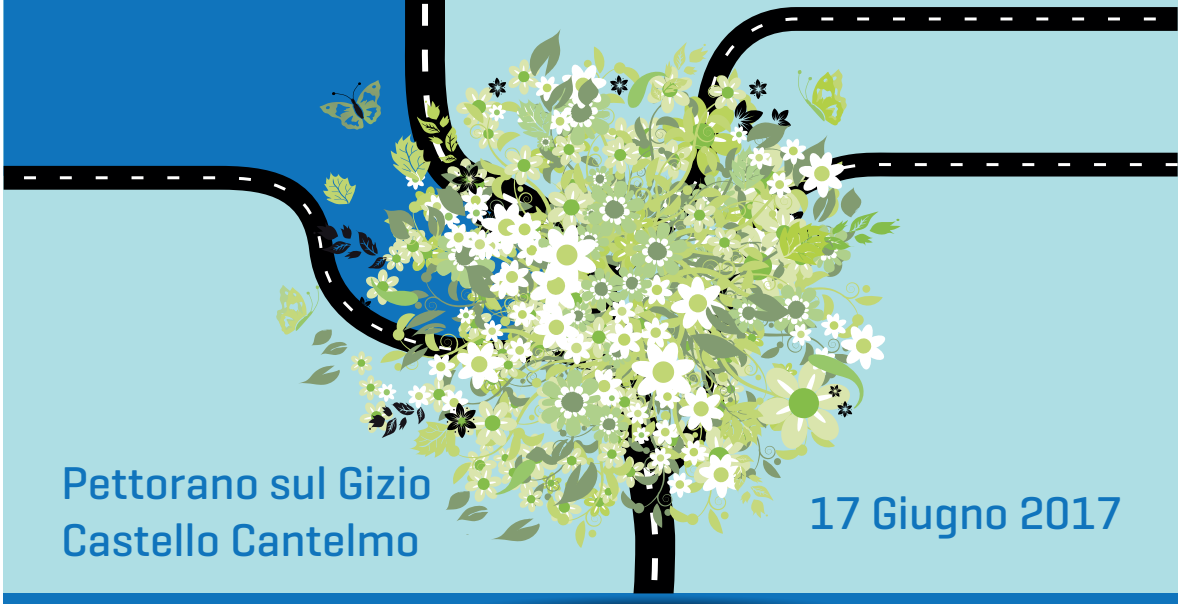
Regione Abruzzo

Comune di Pettorano sul Gizio

Legambiente

IV Conferenza del Centro Studi per le Reti Ecologiche

Road Ecology experiences
Research, planning and design for the ecological sustainability of infrastructures



Pettorano sul Gizio
Castello Cantelmo

17 Giugno 2017

abstract

edited by
M. Fabrizio, S. Ciabò, M. D'Amico, M. Di Febbraro, A. Loy, S. Ricci

I quaderni del Centro Studi per le Reti Ecologiche
Volume 5

Con il patrocinio di

MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE

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IV Conferenza del Centro Studi per le Reti Ecologiche

Road Ecology experiences: research, planning and design for the ecological sustainability of infrastructures

Pettorano sul Gizio, 17 giugno 2017

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I quaderni del Centro Studi per le Reti Ecologiche
Volume 5

COMITATO SCIENTIFICO

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Serena Ciabò (*Università degli Studi dell'Aquila*)
Anna Loy *(Università degli Studi del Molise)*
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CITAZIONE CONSIGLIATA

Fabrizio M., S. Ciabò, M. D'Amico, M. Di Febbraro, A. Loy, S. Ricci, 2017 (eds). Abstract della Quarta Conferenza del Centro Studi per le Reti Ecologiche "Road Ecology experiences: research, planning and design for the ecological sustainability of infrastructures". 17 Giugno 2017 - Pettorano sul Gizio (AQ). I quaderni del Centro Studi per le Reti Ecologiche - Volume 5

La IV Conferenza del Centro Studi per le Reti Ecologiche "Road Ecology experiences: research, planning and design for the ecological sustainability of infrastructures" organizzata dal Centro Studi per le Reti Ecologiche della Riserva Naturale Regionale Monte Genzana Alto Gizio, dal Comune di Pettorano sul Gizio (AQ) e Legambiente Abruzzo Onlus, vuole costituire un momento di raccordo tra tutti i soggetti interessati che afferiscono al mondo della pianificazione e della progettazione tecnica (ingegneria civile, architettura, urbanistica) e delle scienze ambientali in genere (gestione faunistica, agronomia, progettazione di aree verdi, tutela del paesaggio conservazione della natura), nonché del management del territorio e delle infrastrutture (amministratori pubblici, enti gestori delle strade ecc.).

L'intento è comporre un quadro delle più significative esperienze di Road ecology, prendendo in considerazione non soltanto studi di ecologia stradale pura, ma anche tutti quegli esempi di integrazione e contaminazione di questo settore all'interno di lavori di più ampio respiro, come la redazione di piani territoriali o urbanistici, valutazioni ambientali, studi faunistici che prendano in considerazione, tra le questioni affrontate, anche le interferenze tra infrastrutture viarie e le componenti ecosistemiche.

La Road ecology è infatti una disciplina dagli esiti estremamente pragmatici e che pertanto ben si presta a supportare tutti i processi di trasformazione del territorio che inevitabilmente contemplano la presenza di strade (piani territoriali, urbanistici, piani di settore, progetti urbani ed edilizi) ed è interessante confrontarsi su quanto, allo stato attuale, gli strumenti ordinari di gestione territoriali siano pervasi da tali tematiche.

La conferenza è stata patrocinata da: Ministero dell'Ambiente e della Tutela del Territorio e del Mare, Istituto Superiore per la Protezione e Ricerca Ambientale, Università degli Studi dell'Aquila, Infra Eco Network Europe (IENE) Parco Nazionale d'Abruzzo, Lazio e Molise, Parco Nazionale della Majella, Parco Regionale Sirente Velino, Associazione Teriologica Italiana, Riserva Naturale Regionale Calanchi di Atri, Riserva Naturale Regionale Gole del Sagittario, Riserva Naturale Regionale Zompo Lo Schioppo.

Mauro Fabrizio
Direttore della Riserva Naturale
Regionale Monte Genzana Alto Gizio

Ore 9.00 *Apertura segreteria e registrazione partecipanti*

Ore 9.30 *Presentazione del convegno e saluti*
Pasquale Franciosa Sindaco di Pettorano sul Gizio
Augusto De Panfilis Assessore alla Riserva Naturale Regionale Monte Genzana Alto Gizio
Igino Chiuchiarelli Responsabile Uff. Parchi ed Aree Protette della Regione Abruzzo
Mauro Fabrizio Direttore della Riserva Naturale Regionale Monte Genzana Alto Gizio

Ore 10.00 *Inizio lavori* (Coordina **A. Loy**)

Tree-lined roads protection in Italy
A. Porta, M. Devecchi

New perspectives in Road ecology: the need for a switch to population- and ecosystem-level research
M. D'Amico, F. Ascensão, R. Barrientos

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Identifying best practice management of road verges for pollinator habitat conservation.
A. McAleenan, D. Woodward, P. Millar

Ore 11.40 Pausa caffè

Ore 12.00 *Ripresa dei lavori* (Coordina **Paolo Ciucci)**

Exploring potential uses of the New R Package SiMRiv for evaluating the Influence of Roads on Wildlife Movements and Predicting Road Mortality Risk
L. Quaglietta, M. Porto

Road kill risk for the Eurasian badger (Meles meles, Carnivora, Mammalia) in Central italy
M. Fabrizio, M. Di Febbraro, F. Roscioni, A. Loy

An integrated, multi-order modelling approach to investigate behavioral response by brown bears to roads in the Abruzzo Lazio and Molise National Park, Italy
M. Falco, C. Datti, L. Maiorano, P. Ciucci

Using occupancy-detection models to assess the roadkill risk.
M. Ferreira, F. Ascensão, H. M. Pereira

Ore 13.20 *Pausa pranzo*

Ore 15.00 *Inizio lavori* (Coordina **Marcello D'Amico**)

Road-kill patterns in a community of Mediterranean carnivores
R. Barrientos

The LIFE STRADE project: A comprehensive approach to face wildlife traffic collisions
S. Ricci, A. Mertens, R. Mazzei, U. Sergiacomi

Road mortality in Central Italy populations of Green (Hierophis viridiflavus) and Black (H. carbonarius) Whip Snake.
V. Ferri, C. Soccini, Francesco Di Toro, Angelo Cameli

Infrastructure Obstruction Profile (IOP) implemented along the transport infrastructures: the case of the Gole Tremonti, Valle Peligna and Valle del Tirino in the Abruzzo Region (Italy)
M. Spera, B. Romano, A. Marucci, F. Zullo

Analysis of the ecological barrier formed by L'Aquila Urban area
F. Bianchi, A. Marucci, F. Zullo, B. Romano

Quantify population trends for Bufo bufo with Citizen Conservation Action Projects. A case study in Lombardy: the Lake Idro Toads Project.
V. Ferri, C. Soccini, C. Mora, S. Silvestri, M. Zenucchi, R. Fasolo

Connecting habitat for Muscardinus avellanarius
S. Hughes, I. White

Ore 17,00 *Sessione Poster* (Coordina **Mauro Fabrizio**)

Carrying out mitigation measures to make road SP 63 "Simbruina" safe for bears (Ursus arctos marsicanus) between the villages of Capistrello and Serra S. Antonio.
D. Valfrè

Una strada ad alta percorrenza: la S.P. Valle di Vico nella Riserva Naturale Regionale Lago di Vico (VT) e gli impatti sulla fauna.
L. Badalassi, B. Bartoli, G. Puddu, G. Tirone, M. Zapparoli

Analisi degli incidenti stradali dovuti al cinghiale in una strada interna alla R.N.R. Lago di Vico
V. Cippitelli, B. Bartoli, G. Puddu, M. Zapparoli

Preliminary analysis for a characterisation of roadkill sites in the Province of Teramo (Central Italy).
A. Melchiorre, S. Ciabò, M. Biondi

A road risk map for the European polecat (Mustela putorius, Mammalia, Carnivora, Mustelidae) in Italy
L. F. Russo, M. Fabrizio, M. Di Febbraro, A. Loy

Analysis of ecosystems occlusion caused by linear infrastructures in the "Gole di Tremonti", "Valle Peligna" and "Valle del Tirino"
M. Spera, B. Romano, A. Marucci, F. Zullo

Analysis of the fauna mortality caused by vehicular traffic in the areas included between: "Gole Tremonti", "Valle Peligna" and "Valle del Tirino"
M. Spera, B. Romano, A. Marucci, F. Zullo

Tree-lined roads protection in Italy

A. Porta[1]*, M. Devecchi[2]

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Tree-lined roads (or avenues) in European countries represent shared European landscape, cultural, and natural heritage. They are important green infrastructure that should serve Europeans for centuries to come. Avenues are artificial, man-made landscape features which at first sight have little obvious to do with "nature" protection. But Europe still boasts an amazing biodiversity, the reason being the cultural landscapes existing in many regions of Europe for over 6000 years. In the past, motorway construction boomed in response to the increase in road traffic; existing roads were expanded, irregular roads were straightened, and the trees were swept aside in the process. In the 1960s, the Italian writer Gianni Roghi protested against the destruction of 260,000 of the trees lining Italy's roads over a five-year period, "on the pretext that they would be dangerous for drivers. The destruction of the tree-lined avenues has serious consequences on the stability of the road in the presence of clay (or in general not stable) soils too; and the hydrogeological disruption of the territory and in particular of the roads is often due to the cutting of the trees and the lateral woodlands along the roads. Legambiente and other environmental protection organizations in Italy and Europe (BUND in Germany, SPPEF in France, etc.) actively protect tree linen roads and woodlands along the roads, despite local roads laws. In Italy, environmental protection organizations are asking for tree-friendly modifications in roads law. In our work we present the current roads law in Italy and practical conservation examples of tree-lined roads in Piedmont and Northern Italy, where a careful design of plantations for existing roads can lead to a better and cheaper approach than concrete-based standard solutions.

New perspectives in Road Ecology: the need for a switch to population- and ecosystem-level research

Marcello D'Amico[1]*, Fernando Ascensão[2], Rafael Barrientos[2]

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Road ecology is an emerging discipline. Most published studies are still descriptive approximations focusing on road-kills, but also on barrier effect and mitigation measures. In this communication we overview our studies on these topics, aimed to highlight the need for more comprehensive research, focusing on quantifying the impacts of road-kills and barrier effect (but also the effectiveness of mitigation measures) at a population level. On the other hand, the switch to population-level studies should be only the first step to appropriately mitigate the impacts of roads and traffic on biodiversity and ecosystems, and for this reason we furtherly overview in this communication our published and ongoing research on five novel topics in Road ecology. First of all, our studies, among others, showed that roads and traffic can furtherly impact wildlife in unexpected ways, such as for example modifying behavioral responses or facilitating biological invasions. Secondly, several positive effects of roads and traffic on different species have been also described in our studies, but in most cases they entailed underlying ecological traps. Thirdly, we observed both impacts and potential benefits along both paved and unpaved road-networks, and even throughout roadless areas affected by off-road traffic. Similarly, we are now studying how these impacts and potential benefits related with roads and traffic can synergically interact with the impacts and potential benefits related to other infrastructures, such as railways and power lines. Finally, we are also investigating a further level of road- and traffic-related impacts: the disruption of biotic interactions, especially predator-prey dynamics and mutualisms. Overall, the present overview highlights the need for a switch to population-level research which should consider the different impacts and potential benefits related to the existing networks of linear infrastructures. In our opinion, this approach should be the base to appropriately mitigate the impacts of roads and traffic on biodiversity and ecosystems.

S.P.I.A., the app that informs of ungulate-vehicle collision risk

N. Putzu[1]*, D. Bonetto[2], M. Canonico[1], F. Civallero[2], S. Fenoglio[1], G. Manzini[1], D. Massara[1], P.G. Meneguz[3], R. Moriano[3], P. Tizzani[3]

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The problem of ungulate-vehicle collisions (UVCs) is continuously spreading and increasing in importance in many countries. Those mitigation measures which could keep this phenomenon in check need in-depth research into UVCs spatial and temporal distribution, in order to be effective. This work focuses on an area of north-western Italy, the Province of Cuneo, and it has confirmed the concentration of UVCs in the spring and autumn months, and twilight hours. Traffic volume and speed have emerged as the factors which influence most the probability of having a collision in a given road section. Many mitigation measures have proved their inefficacy or unfeasibility, and the need for more innovative and interactive methods has become apparent. Incurring in a UVC is often, in fact, dependent on the driver's reaction: so, informing motorists of those high-risk sectors enables them to be prepared for an animal's presence on the road and adjust behaviour accordingly. Based on our analysis, we decided to develop S.P.I.A. (*Segnalazione Pericolo Investimento Animali,* or "animal collision danger report"), an app for Android, which notifies the user with an auditory signal, when approaching a known high-risk area in certain periods of the year. Based on real data, and on risk modelling, for the first version of the app we have chosen about a hundred road sections located in the study area, the Province of Cuneo. Field tests have returned positive results, and from April 2017 the app is downloadable for free from Google Play Store.

Insularization due to road network: ecological corridors analysis on Umbria Region

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This paper presents the results of an analysis carried out in recent years in Umbria over the regional ecological network project (RERU 3) and the Sun Life Project.
Umbria is one of the few Italian regions where a local designed ecological network has become part of ordinary regulations regarding the urban transformations (ref. Regional law for Territorial Governance no. 1/2015). However, recent studies conducted in the Sun Life project have shown that high biodiversity areas, like the Nature 2000 Sites (16% of the regional territory), are subject to a strong insulation due to the high density of the infrastructure network.
Therefore, we conducted an analysis of the fragmentation caused by roads through the "Infrastructure Obstruction Profiling" (IOP) method, applied in two variants: "in continuous" and "by passages". In continuous: the analysis was applied where the viability is integrated into the context and IOP is presented as a longitudinal diagram of the transportation infrastructure, along which the degree of interference is expressed in consideration of the entity and the typology of obstacles that are present.
By passages: the method was used when the viability is isolated from the context by invalicable lateral barriers and thus it can only be crossed where there are discontinuities (bridges, viaducts etc).
Approximately 380 passages for potential biotic flows were detected on 315 km of roads examined.
However, almost 300 of these serve to bypass other roads. Crossings with more ecological fitness are: 37 fluvial ones, 26 morphological ones and 15 tunnels on a total of about 25 km.
Among these, some strategic passages for the regional ecosystem continuity were selected, currently not disturbed and not affected by forecasts of urban plans. These high vulnerability areas should be included in a future regulatory framework for the review of the RERU.

Identifying best practice management of road verges for pollinator habitat conservation

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Pollinators in Ireland and across the world are in decline. A global commitment to conserve their abundance and diversity is required to ensure sustainable food production and healthy natural environments.

Pollinators require a balanced diet and necessitate more than monocultural crop diets to remain healthy. Since the advent of intensive farming Europe's species-rich habitats have been in a steep decline, the British Isles have 2% of that which existed in the 1940s. Wild pollinators require native species-rich habitat, including; grasslands, dune systems and road verges.

Road verges have an important role to play. Alongside the creation of food and nesting habitats, they are valuable as linking corridors between different pollinator appropriate patches. Much current work concentrates on creating species-rich habitat in the context of agriculture or public spaces; this study concentrates on road verges. It aims to identify the best management treatment to advise those creating new road infrastructure and for those whom manage existing road networks. Correctly maintained road verges provide shelter for wildflowers, create mini meadow corridors and inevitably preserve pollinator abundance and diversity.

Identification of research sites across Northern Ireland has been undertaken with three key verge treatments to be studied: regular cutting, cut once/twice annually, and seeded with wildflower mix and cut once/twice annually. Identification of the native floral species and their associated pollinators, particularly bumblebees (*Bombus Spp*). The expected relevant abundances and diversity of floral species to create a sustainable food source and a healthy natural environment have been estimated to help identify the best management practice for pollinator conservation.

Exploring potential uses of the new R Package SiMRiv for evaluating the influence of roads on wildlife movements and predicting road mortality risk

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Road mortality represents a serious and increasingly common threat to wildlife, including organisms, like semiaquatic mammals (e.g., otters, minks), which, by mostly moving along watercourses, and therefore potentially crossing roads less frequently than more terrestrial species, should be theoretically less subject to road-kills. An important topic of research is therefore to understand how roads influence animal movement, and predict the location of road kill hotspots, to undertake adequate mitigating measures. Here we explore potential uses of our new recently developed open source software, the R package *SiMRiv*, in the subject of road ecology. Although the software was originally conceived to simulate spatially-explicit individual multi-state (animal) movements in river, heterogeneous, and homogeneous landscapes, thus filling an important gap in the available tools to study animals that move mainly within river networks (e.g., semiaquatic mammals), *SiMRiv* can indeed be used to test the effects of any landscape feature on the movement patterns of any species. We performed a simulation study evaluating the use of *SiMRiv* to: (i) test the effects of roads on real otter movement patterns, and (ii) predict road-kill high risk areas. To do so, we compared: (ia) true and simulated otter movement parameters near and far from roads, (ib) true otter movements with null models (simulated, multi-state markov movements) of increasing complexity, and (iia) areas of predicted high road-kill risk identified by the top kernel density contours of simulated otter movements with true otter road-kills events. We present preliminary results of our study and integrate their discussion with an overview of potential uses of *SiMRiv* as a tool to help biologists to test a series of road ecology mechanistic hypotheses.

Road kill risk for the Eurasian badger (*Meles meles, Carnivora, Mammalia*) in Central Italy

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Road mortality is the largest single cause of death for many species and it is a growing phenomenon.

Long-lived and slow reproducing carnivores like the Eurasian badger (*Meles meles*) are particularly vulnerable to road mortality, as they tend to frequently cross unfamiliar habitats such as roads. We produced a road risk map for the badger to identify optimal sites for mitigation measure in Abruzzo (Central Italy). To obtain the road risk map, we used a Species Distribution Model (SDM) approach combining 54 data of road collisions collected between 2007 and 2016 with six predictors rasterized at 250 m resolution: Euclidean distance from urban areas, density of local and regional-state roads, highway density and badger habitat suitability and functional connectivity. Habitat suitability was calculated by means of a SDM relating 94 sightings of live badgers with NDVI, elevation, slope and aspect. Functional connectivity was modelled through the Circuitscape software using as nodes 100 presence records randomly selected in the region and as resistance a layer built through an expert based approach scoring high value to landscape features that impeded the species movement (e.g. highways) and low value to those features that allow a good mobility (e.g. cultivation). Road risk map reported a good level of predictive accuracy as indicated by ROC and TSS mean values of 0.811 and 0.560, respectively. Predictors that most affected the modelled road risk map were the regional roads density and the connectivity. These results indicate the regional roads as the most risky ones.

Besides, inside each regional road, it is possible to find a vulnerability rate from medium to high, mainly given by the habitat suitability for the species.

An integrated, multi-order modelling approach to investigate behavioral response by brown bears to roads in the Abruzzo, Lazio and Molise National Park, Italy

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Since the 1970s, at least 13 Apennine brown bears (*Ursus arctos marsicanus*), including reproductive females, were killed in vehicle collisions in the Abruzzo Lazio and Molise National Park and adjacent areas (PNALM). However, little is known about road-crossing behavior by bears in the PNALM, whereas this knowledge is essential not only to enhance the efficacy of prevention measures but also to assess the effects of roads on space-use patterns by bears. By focusing on primary (main paved) and secondary (secondary paved and gravel) roads, we investigated the within-home range behavioral response by bears to roads and their road-crossing behavior. By using Global Positioning System locations recorded from 18 adult (11 females and 7 males) brown bears in the PNALM (2006-2010), and an integrated, multi-order (i.e., III and IV Johnson's orders of selection) modelling approach within a Resource Selection Functions framework, our aims were to: (i) model the frequency of road-crossing (main paved roads) by bears, as a function of sex, season, home range location, and time of the day; (ii) assess within-home behavioral response by bears to roads by contemplating a set of environmental and anthropogenic predictors, and (iii) define the environmental, orographic, and anthropogenic context that most characterize road-crossing sites (main paved roads only) used by bears. We hereby show the potentiality of integrating the functionality of R packages (*adehabitat HR, adehabitat LT, lme4, MuMin*) and GPS telemetry data into a GIS environment (ArcMAP, v. 10.2 ESRI) as a means to investigate and eventually mitigate negative effects of roads on wildlife species.

Using occupancy-detection models to assess the roadkill risk

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Accurate prediction of wildlife-vehicle collisions (WVCs) is a major concern in Road Ecology, being important base information for deciding where to implement mitigation measures. Yet, such predictions are prone to biases, including the failure to detect WVCs in road surveys, i.e., imperfect detection.

We suggest using occupancy-detection models to analyze roadkill data to reduce the uncertainty on roadkill risk predictions. We considered the occupancy as the probability that individuals of a given species use a road section (or its immediate vicinity), for crossing, foraging, etc. therefore being exposed to WVC (roadkill risk); and detectability is the joint effect of the probability of an individual being hit by a vehicle and the probability of its carcass being detected during a roadkill survey. We developed a framework within this approach to assess how habitat influences species roadkill risk (occupancy probability) along the roads, while accounting for imperfect detection (carcass removal).

We used simulated data to compare simple occupation-detection model to traditional modeling framework (GLMs). Preliminary results show that GLMs are able to identify the road sections with higher roadkill probability, but fail to identify sections with intermedium roadkill risk or with high rate of carcass removal. Accounting for imperfect detection, even with constant detection probability, improves the identification of road sections with important roadkill risk.

We believe that occupancy models can provide improved information for management guidelines. We urge practitioners to take to account this issue when planning road monitoring schemes. Data collection should be designed to collect information that allows the implementation of this framework. Further model development will allow disentangling both detectability processes.

Road-kill patterns in a community of Mediterranean carnivores

R. Barrientos[1]*

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The road network causes barrier effect, habitat lost and fragmentation for several wildlife species subdividing populations or reducing the habitat carrying capacity. However, the most evident impact of roads is mortality due to road-kills. The sum of all these factors affects wildlife population sizes, thus potentially threatening their viability in the long run. From a population perspective, road impact is higher for predators as they have low fecundity, small population sizes and large home-ranges. Also, predators are important for maintaining ecosystem function, structure and services, being commonly considered flagship species. I studied the road-kill patterns in a community of Mediterranean mesocarnivores composed by seven species - red fox (*Vulpes vulpes*), stone marten (*Martes foina*), Eurasian badger (*Meles meles*), European polecat (*Mustela putorius*), common genet (*Genetta genetta*), Egyptian mongoose (*Herpestes ichneumon*) and European wildcat (*Felis silvestris*)- from central Spain during two years. I compared the abundance of road-kills with the relative abundance of carnivores to investigate if some species were road-killed over expected relative to their abundances. I found road-killed individuals from all species but the badger, the most affected being polecat (58%), red fox (20%) and mongoose (11%). I found that species like polecat were more represented in road-kills than expected, and others like fox were underrepresented. Most of road-kills happened during September (20%), June (11%) and July (11%), and this trend (more road-kills in summer) was similar to all species. I discuss potential causes of the patterns found.

The LIFE STRADE project: a comprehensive approach to face wildlife traffic collisions

S. Ricci[1]*, A. Mertens[1], R. Mazzei[1], U. Sergiacomi[1]

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Road traffic is an increasing cause of wildlife mortality, both in terms of the expansion of transport infrastructures as well as of the increasing number of circulating vehicles.

In Italy there is a lack of accurate estimates of the real impact of vehicular traffic on biodiversity, although this phenomenon is constantly increasing and causes also serious problems for driver safety. Moreover, it is an important problem due to economic reasons related to damage compensation.

The LIFE STRADE project, which started in 2013 and ended on 31thMarch 2017, faced the problem of wildlife traffic collisions in central Italy.

The project involved 3 Regions (Umbria, Toscana, Marche) and 5 Provinces (Perugia, Terni, Siena, Grosseto, e Pesaro-Urbino)

The main objectives were:

- to develop and test an innovative system for the prevention of road collisions with wildlife, which simultaneously alerts drivers and, if they do not slow down, scares away the animals off the road sides;
- to develop a common road kill monitoring and prevention protocol, shared by the three involved regional governments;
- to disseminate the tools and best practices developed at national and international level.

Totally 17 prevention devices have been installed in the 5 Provinces and their effectiveness has bee measured in terms of the reduction of wildlife traffic collisions, and in terms of "risky situations" avoided thanks to the system's interventions. A geodatabase containing 5.027 records of animals found dead along the roads of the five involved Provinces was developed, and the information gathered has been used to produce risk maps. The monitoring and management protocol signed by the 3 Regions will ensure the continuation of activity in the next years.

Finally, extensive information campaigns have been carried out in order to increase public awareness about the issue of wildlife-traffic collisions, and the opinions of citizens have been registered through specific surveys in the first and last years of the project.

In conclusion, we believe that the experience gained during project implementation represents an important example, to be exsported in Italy and elsewhere in Europe.

Road mortality in Central Italy populations of green (*Hierophis viridiflavus*) and black (*H. carbonarius*) whip snake

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Recently Whip snake, the most common and widespread snake in Italy, was genetically distincted into two species: Green whip snake, *Hierophis viridiflavus* and Black whip snake, *H. carbonarius*, integrating and confirming subspecific differences and particularities already underlined and highlighted. It follows that all are now studying possible and any differences between two species at level of behavior, ecology and biology.

We describe differential road mortality across two species as result of a long-term research carried out in road sections comparable in length, crossed environment and volume of traffic, located in the central part of their Italian distinct areal.

Estimated roadkill rate of *Hierophis viridiflavus,* during March-October of 2010-2016 in a 16.2 km stretch of road located in the Viterbo Province (North of Latium) was 1.09 individuals/km/year, more higher than *H. carbonarius'* roadkill rate, during April-October of 2013-2015 in a 18 km stretch of road located in the Teramo province (North of Abruzzo), that was 0.15 individuals/km/year. Mortality varied significantly across the study period, with the greatest number of kills recorded in early May to mid June. We observed male-biased sex ratios in both study areas and species. Approximately 78% of carcasses of *H. viridiflavus* was found within a lateral band of about 70 cm roadway and this suggests that most of the snakes were intent on thermoregulating or were beginning or ending the crossing of the road.

Snake populations are sensitive to the fragmentary effects of roads, because of their reliance on resources that vary seasonally and are patchily distributed. To reduce mortality of Whip Snakes during their peak activity periods it will be needed a combination of public education, heightened awareness via snake crossing signs, and reduced speed limits in known focus area for snakes.

Analysis of the ecological barrier formed by L'Aquila urban area

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In the urban spatial planning, the residual areas, the so called "openings", are topic of great interest. They represents those portions of strategic territory for biotic connections made up of areas not yet affected by urbanization. The work has been developed with the cooperation of the Municipality of L'Aquila and the University of L'Aquila for the drafting of the new General Controller Plan of the city. By the identification of the existing infrastructural openings within the urban barrier, was analyzed the degree of disturbance and, at the same time, it was possible identified some ecological connection lines to reduce the fragmentation process due to the urbanization. The urban barrier is 20 km long and 210 openings have been detected inside it, whose linear length is 8.42 km, constituting 5,45% of free surface of the length (154 km) of the considered infrastructures (common road, motorway and railway). It is really interesting the identification of the residual spaces that have the function of an ecological network, especially in the north-south direction between the two high biodiversity areas represented by the "Gran Sasso-Monti della Laga National Park" (North) and the "Sirente-Velino Regional Park" (South). There are four possible connection lines, for each of them, technical proposals have been developed to improve the existing ecological conditions.

Infrastructure Obstruction Profile (IOP) implemented along the transport infrastructures: the case of the Gole Tremonti,Valle Peligna and Valle del Tirino in the Abruzzo Region (Italy)

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This study was carried out over a decade (2006-2016) and it was aimed at characterizing the degree of ecosystem fragmentation, determined by linear transport infrastructures, in three macro-regions of Abruzzo: the Gole Tremonti, Valle Peligna and the Tirino Valley.

The study area includes 51 municipalities and comprises 10 SCIs, 3 SPAs and 4 protected areas: Majella National Park, Gran Sasso-Laga National Park, Sirente-Velino Regional Park and Regional Reserve of Genzana Mount. The analytical approach provided for a preliminary division into two concentric sectors: an external sector limited by the main Apennine range mountains that on a large scale forms the ecosystemic context of the ecological network and a second sector, placed inside the first one, represents an "anthropic hot spot", distinguished by various types of urbanization and especially by several types of infrastructures.

The study concerned the road mortality monitoring and the formulation of Infrastructure Obstruction Profiling (IOP).

The analysis of road mortality was carried out over a period of 14 months (from February 2006 to March 2007), during which 95 sampling was conducted for a total of 4.838 km (round trip), with the finding of 186 road-kiled animals.

As far as the IOP is concerned, the investigated infrastructures amounts to approximately 100 km divided into 37 km of highway, 24 km of railway and 39 km of ordinary road network (3 regional roads).

The result of the territorial analysis has allowed the characterization and georeferencing of the present structural elements, their classification according to the degree of species-specific occlusion along with the definition of the main faunistic permeability corridors and the identification of ecosystemic critical areas.

Quantifying population trends of *Bufo bufo* through Citizen Conservation Action Projects. A case study in Lombardy: the Idro Lake's Toads Project

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Long-time data series on amphibian population dynamics are necessary to distinguish declines from the often strong year-to-year fluctuations observed in natural populations. However, amphibians show a very complex life cycle in which density-dependent regulation may occur at the larval, juvenile and adult stages and their decline may be affected by predators, competitors and environmental variables, acting on reproduction and survival. In this paper we provide data from one of the longest census study on one Italian *Bufo bufo* population: that on the left bank of Idro Lake (Brescia Province, Northern Italy). In this area, since 1997, annual rescue campaigns of migratory amphibians are carried out by volunteers. "Idro Lake" is also one of oldest "Toads Project" in Italy.

As already described for rescue operations on roads in other European locations numerical fluctuations of a common toad population can be very wide. Long-term monitoring studies show that these fluctuations have cycles of 6-7 years. This means that it would take about 12 years to reach the peak number in a natural population of *B. bufo*. The analysis of data from 20 years, collected with the help of volunteers of the "Idro Lake Toads Project", a viable and successful Citizen Science project, shows this natural fluctuation and it suggests that the decline recorded in the previous years was not due to environmental deterioration or to human interventions. These results, supported by those from other similar initiatives in Lombardy, could indicate that the periodic decline observed in migrant *B. bufo* populations, does not necessarily imply an irreversible trend towards extinction, as some recent studies suggest.

Connecting habitat for *Muscardinus avellanarius*

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The ever-increasing global transport network has the potential to fragment habitats utilised by the arboreal European hazel dormouse *Muscardinus avellanarius*. This prompts the need for evidence-based, effective mitigation to maintain ecological connectivity in human-influenced habitat fragmentation situations. Although a number of 'wildlife bridges' have been installed to allow habitat connectivity for Hazel Dormice, many approved designs have been demonstrated to be both expensive and ineffective, highlighting the requirement for further research into affordable and reliable alternatives.

We will consider how historic research conducted in Japan has influenced a recent UK study by the People's Trust For Endangered Species (PTES) and Animex Mitigation Solutions, which has led to the development of a new, affordable wildlife bridge with proven effectiveness in enabling Dormice to travel through fragmented habitats.

A bridge adapted from the original Japanese design was installed on the Isle of Wight, UK, connecting two known areas of Dormouse habitat dissected by a railway line. Exclusion fencing, with periodic entry points, was installed along both sides of the railway, with motion-activated cameras positioned along the bridge and at each entry point along the fencing.

The results of the UK study confirmed the use of the arboreal bridge by Hazel Dormouse, with a higher number of Dormice recorded on the bridge than at ground level, demonstrating a clear preference for arboreal dispersal.

Following the proven effectiveness of this adapted bridge design Animex is working with a municipal council to produce a cost-effective, modular design that can be easily distributed and installed on construction mitigation projects. Annual *in situ* monitoring will be necessary of bridges to determine individual success, and ongoing research is being undertaken to establish how this design can be utilised and adapted to reconnect habitat networks for other species around the globe.

Carrying out mitigation measures to make road SP 63 "Simbruina" safe for bears (*Ursus arctos marsicanus*) between the villages of Capistrello and Serra S. Antonio

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Vehicular traffic on the roads that cross the habitat of the Marsican brown bear in the buffer zone between the Abruzzo, Lazio and Molise National Park and Simbruini and Ernici mountains in particular are a continuous threat to this species and it has been the cause of death of several bears. According to data which have been recently published by the Abruzzo, Lazio and Molise NP, in a total amount of 93 casualties in the period 1971 – 2013, 9 bears were killed by cars (9.67 %), while five bears by trains (5.37 %).

"Salviamo l'Orso" analyzed the roads that cross some parts of the Marsican brown bear core area to detect the most dangerous segments. Salviamo l'Orso then determined where to set reflective studs, road signs and optical hold-up systems, in addition, they reduced the speed limit to 60 km/h. These interventions will hopefully dramatically reduce the wildlife road death rate, whilst increasing drivers' safety.

The intervention area is a wildlife crossing (wildlife corridor) between two critical areas for bears - i.e. the mountains of Serra Lunga and the mountains of Catena del Renga-Mount Viperella-Mount Cotento-Mount Viglio-Cantari - which is rich in fruit trees and food sources, near to human-populated territories crossed by Road SP 63 "Simbruina" in the segments between Capistrello – Serra S. Antonio.

Una strada ad alta percorrenza: la S.P. Valle di Vico nella Riserva Naturale Regionale Lago di Vico (VT) e gli impatti sulla fauna

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Aim of this work is to present "road kill" data of the impact of a very busy road "SP Valle di Vico" (provincial road), within the protected area "Lago di Vico" Natural Reserve (Caprarola, VT). For the data-processing, two phases have been implemented: a preliminary data collection of "road-killing" fauna and environmental data (CLC categories), to verify the existence of higher concentration zones of alerts, and a second phase to monitoring that zones, to propose technical solutions for environmental defragmentation and mitigation, taking into account the representativeness of the frequency of species dead in the road-killing. The road we have considered is 16 kilometers long and crosses different environmental typologies (scattered buildings, agricultural areas, wooded areas, meadows), two SCI (Sites of Community Importance) and represents an important barrier for the movement of wildlife exploiting different types of forests and territories for its existence. For wildlife other than wild boar, the analysis shows a dispersion of reports, although they can be related to areas linked mainly to the presence of territories strongly characterized by anthropic use such as the urban sprawl (presence of a housing parcel) and agricultural areas with permanent woody cultivations (presence of hazelnuts cultivation). On the other hand, regarding wild boar, the reports are very well circumscribed to suggest a preferential way of moving between vital areas for the species. In some sections, the road appears unmodifiable and cannot be mitigated. A last but not least important strategy would be to raise awareness using road signs to illustrate the problem.

Analisi degli incidenti stradali dovuti al cinghiale in una strada interna alla R.N.R. Lago di Vico

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Road accidents caused by collisions with wild boar are an increasing problem for the "Lago di Vico" Natural Reserve (Caprarola, VT), both for the risk for human life and for claims for economic compensation, as well as for the overall ecological impacts. In order to take measures to mitigate or solve the problem, an analysis of the claims (n = 33) received at the Reserve (2004-2017) has been made. It has highlighted the presence of a specific area where the highest number of accidents occurs (n = 18), linked to the presence of large wooded areas, straight road tracts that lead to overcoming speed limits, vegetation bands close to the roadway. By dividing the 24 hours with time-budget techniques, there is a strong difference in the number of day (n = 5) and night accidents (n = 20), with high significance (P> 0.01 **). The number of accidents occurring during the weekend (Sat-Sun, n = 15) are similar to those occurring during the week (Mon-Fri; n= 18), but their frequency is double compared to the latter. Part of the analysis of collected data has aimed at identifying general descriptors that can help identify similar situations in other territories. For the road segment with the higher accident rate, it is possible to contemplate few mitigation actions: road signs that attract the attention of the drivers, especially at nighttime, constant maintenance of the vegetation along the roadside to increase visibility. It is not always possible to carry out interventions as underpasses because the overall environmental conditions do not provide adequate spaces.

Preliminary analysis for a characterisation of roadkill sites in the Province of Teramo (Central Italy)

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This master thesis aims to identify the spots where road accidents with mammals have occurred in the Province of Teramo.

The area examined is very diversified because it covers the cost up to the highest peak of Gran Sasso, the Corno Grande in the Center of the Appennine, passing through the hill country. Gran Sasso and Monti della Laga National Park occupies 28% of this territory and in the foothills and hill country there are four small SCI(s). All the tipical fauna of the central Appennine is potentially present within this frame.

This work has analyzed incidents affecting medium and large mammals in order to pinpoint potential road sections that present high levels of criticality and characterise road kill sites. The main goal of this characterisation is to provide general elements necessary to introduce appropriate mitigation measures.

Data analyzed are the result of random reports, originating either from scientific experiences, as in the case of the data in the ecological network studies center database, or from claims for damages submitted to the Province of Teramo.

In total, 135 events have been taken into consideration between 2003 and 2016. These data have been entered into a database and, thus, classified using parameters such as the species involved in the accidents, the type of road, the structure, the lateral barriers, the morphology and the roadsid habitat.

The most affected species is ungulates (wild boar and roe deer), especially in territories adjacent to the national park and on roads in the countryside.

Based on the information collected, site-specific mitigation measures will be proposed in agreement with road management authorities.

A road risk map for the European polecat (*Mustela putorius, Mammalia, Carnivora, Mustelidae*) in Italy

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The growing numbers of road infrastructure have a great impact on biodiversity, such as habitat loss, degradation, fragmentation and roads impacts. The European polecat (*Mustela putorius*) is a small-sized, elusive and poorly studied carnivore that is often found along roads.

We collected 223 records of polecat road casualties in Italy and analysed the relationships with land-cover categories to evaluate factors influencing the risk of road collisions. A buffer of 3 km radius, corresponding to the average home range size of the polecat, was created around each collision site. Within each buffer, we computed the area of each Corine Land Cover category (CLC, III level, 1:250 000). We generate 10000 random points with 3 km buffer along Italian roads to characterize the CLC coverage of the environment. Wilcoxon signed-rank tests were used to check for differences in extent of land-cover categories between road collisions sites and random points. Rice fields (2.1.3), Broad-leaved forests (3.1.1) and Water bodies were significantly overrepresented around collision sites than in background points. Several categories from agricultural areas (i.e. 2.2.3, 2.3.1, 2.4.1, and 2.4.2), forest and seminatural areas (i.e. 3.1.2, 3.1.3, 3.2.2, 3.3.2, and 3.3.4) and wetlands (i.e. 4.1.1) were significantly underrepresented around collision sites than in background points. We discuss the results in the light of known habitat preferences of the species, and dispersal routes.

Analysis of ecosystems occlusion caused by linear infrastructures in the Gole di Tremonti, Valle Peligna and Valle del Tirino

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This study has been performed in about a decade (2006-2016), with the purpose to define the level of ecosystem fragmentation determined by linear infrastructures in three macro-regions of Abruzzo which are: Gole di Tremonti, Valle Peligna and Valle del Tirino.
The area of the research includes in total 51 municipalities and includes 10 SICs, three SPAs and four protected areas: Majella National Park, Gran Sasso-Laga National Park, Sirente-Velino Regional Park and Regional Natural Reserve of Genzana Mountain. The analytical approach contemplate a preliminary partition into two concentric sectors; one external limited by the main group of mountains which mostly consists in the structure of the ecosystemic context among the ecological network; the second internal sector, included in the first one, acts as an "anthropic hotspot", featured by the presence of a complex infrastructural bundle and with different kinds of urbanisation. The analysis was performed by monitoring the road mortality and the implementation of the ecosystemic occlusion profile (PdO). The length of the infrastructural bundle monitorated is about 100 km divided into 37 km of motorway, 24 km of railway and 39 km of ordinary road network (3 regional roads). The analysis of the fauna mortality caused from vehicular traffic was monitored during a period of 14 months (February 2006 to March 2007). During this time frame 95 sampling were obtained for a total of 4.838 km (round trip) and finding along the trail 186 animals hit to death. The methodology of analysis, based on the PdO, has foreseen the preliminary importance of all the structural elements present along the infrastructures (guardrails, walls, fences and mixed forms). These elements were subsequently classified according to their potential species-specific barrier role. The analytical synthesis of the conducted studies is represented by a diagram (PdO) that describes sequentially, in a complete and immediate manner and with several chromatic scales, the level of ecosystem occlusion in each infrastructural segment. The last territorial analysis has allowed the characterization and georeferencing of the courrent structural elements; their classification according to the level of species-specific occlusion and, above all, the definition of the main trajectories of fauna's permeability and the identification of areas with ecosistemic critical.

Analysis of the fauna mortality caused by vehicular traffic in the areas included between: Gole Tremonti, Valle Peligna and Valle del Tirino

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This study has been performed during the two-year period 2006-2007 and the purpose was to define the phenomenology of fauna mortality caused by vehicular traffic in three following macro-areas of Abruzzo: Gole di Tremonti, Valle Peligna and Valle del Tirino.

The infrastructures included in this research were in total four: SRn5 Tiburtina Valeria (14 km), SRn153 Valle del Tirino (14 km), SRn17 Appennino Abruzzese (5.5 km) and the fast road in the direction of Sulmona (6 Km) for a total extension of 39.5 km. This infrastructure bundle crosses the territory of 8 municipalities and it share the territory with four SIC, 2 SPAs and 2 protected areas such as Majella National Park and Gran Sasso-Laga National Park. The analytical approach contemplates a preliminary partition of the infrastructural areas in almost uniform segments in order to maximise sampling frequency and to keep the regular sampling cycle along each segment.

95 sampling were performed between February 2006 and March 2007 and only 14 of these were null (14.74%). A total of 2.419 km has been monitored (for a total of 4.838 km round trip) finding along the trail 186 animals hit to death. The most affected class is the Mammals (114 equal to 61.29%) followed by the Birds (33 equal to 17.74%), then amphibia (25, only toads), Reptiles (11 equal to 5.91 %) And three unknown specimens. The most affected species were the hedgehog (41), the toad (25), the domestic cat (20), the squirrel (18) and the fox (20). From a statistical point of view, monthly mortal accidents averages were calculated and for each infrastructure and infrastructure segment together with the correlation between the amount of kilometres travelled and the number of detected specimens was classified as "Index of mortal accidents per Kilometre". The latter allowed from one side to estimate the sampling effort (i.e. the minimum amount of kilometres travelled in order to find a certain number of specimens) and on the other side has contributed to the identification of the infrastructural fragment most affected by the road mortal incidence.

Accurate territorial analysis was finally able to mark the most ubiquitous species (e.g. hedgehog and fox) from those most linked to environmental or seasonal factors (e.g. squirrel, domestic cat and toad).

Road Ecology experiences

Research, planning and design for the ecological sustainability of infrastructures