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## Chapter 12

# Wildlife Impacts *Birds & Insects*

### **DRAFT GUIDELINES FOR DEVELOPMENT OF CONSERVATION ALTERNATIVE MOWING PLANS FOR INTERSTATE, EXPRESSWAY AND PARKWAY ROADSIDES**

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**Abstract:** A primary responsibility of the New York State Department of Transportation (NYSDOT) is to maintain a highway right of way that is safe for the traveling public. Most often, this requires removal of trees, shrubs, and other fixed objects that may stand in the way of drivers leaving the highway. For many years, the department has fulfilled this responsibility by large scale clearing and mowing of a clear zone. Roadside management practices that maintain the right of way as parkland certainly make the road safe and visually pleasing, but provide little in the way of useful habitat for wildlife. The clear zone, occupying approximately 1 percent of the state's land area, is a landscape that has much potential for providing nesting and foraging habitat for grassland bird species. Protection of the environment being another responsibility of the department, the NYSDOT needs to advance practices that promote wildlife use of habitats along the highway, while maintaining a safe and aesthetic roadside for the travelers.

#### **Project Objective**

The project objective is to maintain a safe, visually pleasing, and manageable roadside environment for the traveling public, while developing habitat management practices for roadside landscapes that promote protection and sustainability of grassland bird species, endangered species and other wildlife.

#### **Funding Source and Total Budget**

Funding for advancement of management practices will be from the general department operating budget.

#### **Methodology**

Over the past three years, some department regions have shifted their roadside clearing and mowing practices to more fully address wildlife issues within the right of way. Efforts are underway to incorporate any practices already underway throughout the state into a statewide roadside management program, which will be manifested in the form of an updated statewide mowing manual. Habitat management methods employed by other state DOT's are being investigated for incorporation into NYSDOT's mowing and roadside habitat management program. Independent research will be conducted by local universities on grassland bird species to investigate habitat needs and characteristics of roadside habitats.

#### **Summary**

This presentation will discuss mowing practices currently employed by the department and recent efforts made to do things differently along NYSDOT roadsides. With an enhanced environmental awareness and increased biological staff throughout the department, work on managing roadsides for wildlife has increased dramatically. Examples of innovative stewardship activities and endeavors to promote grassland habitats and typical bird species found in these environs will be presented. The process of revising the statewide mowing manual to incorporate habitat management will be reviewed. Implications of the Migratory Bird Treaty Act on roadside and bridge projects will be briefly discussed.

#### **Future Research and Policy Development**

Roadside habitat management is a topic with many unknown aspects for a transportation department. Many opportunities exist for research on how best to manage the landscape for wildlife while still providing a safe and pleasing roadside. As the department moves forward in an ever-expanding role of stewardship of the natural environment, development of roadside management policies will be crucial.

#### **Introduction**

Maintenance mowing along interstate, expressway and parkway roadsides is essential to motorist safety, corridor aesthetics, maintenance of structures/facilities and worker and public satisfaction. General NYSDOT mowing guidelines are outlined in the department's "Mowing Manual," "Highway Maintenance Subdivision Operational Guidelines" and "Environmental Handbook for Transportation Operations." The following material provides a suggested approach to developing Conservation Alternative Mowing Plans (CAMPs) that will not compromise existing standards for safety, aesthetics and routine maintenance, and may:

- Conserve staff hours spent mowing
- Conserve fuel usage and costs
- Conserve air quality through reduced spent fuel emissions
- Conserve habitat for protected and declining populations of ground nesting birds including Eastern Meadowlark, Bobolink, Savanna Sparrow, Song Sparrow, Grasshopper Sparrow, Henslow's Sparrow and Upland Sandpiper
- Conserve required equipment maintenance
- Conserve habitats through reduced fragmentation

Conservation alternative mowing plans have been successfully developed and implemented on interstates, expressways and parkways in NYSDOT Region 5 through a multi-disciplinary team approach (and to varying degrees in other regions as well).

Four (4) zones are recommended for interstates, expressways and parkways. The names of these zones vary from those indicated in the Mowing Limits Manual. The new names better describe to the operators what management is expected in the different zones. The name of the zone, as described in the Mowing Limits Manual, is in parentheses.

- **High Management Zone** (*High Management Zone, Mowing Limits Manual, MLM*) - intensely managed area immediately adjacent to shoulder or curb
- **Frequently Mowed Zone** (*Moderate Management Zone, MLM*) - High maintenance area, mowed frequently (x times/ year)
- **Annually Mowed Zone** (Not addressed in MLM) - transition between Frequently Mowed Zone and No-Mow Zone (or left to regenerate naturally)
- **No-Mow Zone** (Minimal Management Zone, MLM) - zone where area left in natural state or left to regenerate naturally

Generally, the Frequently Mowed Zone will be 30 feet in width or will be set at the back side of the drainage ditch. The limits of this zone may be reduced or extend further depending on actual site conditions.

The limits of the Frequently Mowed Zone may require adjustment to preclude the development of annually mowed areas that are too narrow (less than 60 feet wide), too small (less than ½ acre), or too linear. Annually Mowed Zones will not be mowed until after August 1st. Annually mowed zones should be mowed no more than once per year; however, to further increase the conservation benefits, these areas may be mowed less frequently, but with due consideration of the desire to limit establishment of woody plants within periodically mowed zones.

The decision to include an annually mowed zone should consider many factors including, the adjacent land use and the width and length of the area. Since the annually mowed zone is important for ground nesting birds, these areas should be at least 60 feet in width and greater than one-half acre in size to reduce nest predation and allow a large enough nesting territory. Annually mowed areas will be most effective when located adjacent to or in close proximity to existing grassy fields and in these situations should extend to the limits of the R.O.W. When the adjacent land use is mature forest, the annually mowed zone should not be included or should be combined with a no-mow zone, as appropriate.

For consistency, Mowing Limit Markers should only be placed at the transition between the Annually Mowed Zone and the No-Mow Zone (the markers can be placed to create a natural appearing, meandering boundary.) Markers should be standard wooden or fiberglass stakes. Over time, the need for these markers should diminish as the demarcation of the zones becomes well established. These zones should also be captured electronically using GPS.

The Mowing Limit Markers shall be installed pursuant to guidance in the MLM and shall also be placed with due consideration of sight distance. This is especially important at entrance/exit ramps. The No-Mow Zone shall not encroach into the sight distance cone and restrict visibility.

The No-Mow Zone can be left to regenerate naturally. This process is termed succession. The final stage of succession is a self-perpetuating, sustainable, and interdependent community of plant and animal life. The establishment of No-Mow zones is intended, in part, to permanently reduce the amount of mowed area and to reduce the negative environmental effects of habitat fragmentation.

On narrow medians (less than 120 feet between the High Management Zones), new No-Mow zones may be established between the 30-foot minimum Frequently Mowed Zones with due consideration for maintenance structures, such as drainage ditches, deer reflectors, living snowfences, etc.

New woody plantings can be included to the No-Mow Zone. The purpose of these plantings should be to increase diversity of the plant community.

Careful consideration shall be given to any new planting of trees and/or shrubs in the Annually Mowed Zone. Decisions to plant trees should reflect the clear zone and clear area guidance found in the *Highway Design Manual* Chapter 10, Section 10.2.1. In addition, new plantings should be grouped in such a manner as to preclude the necessity of maintenance personnel to mow around individual plants. Supplemental (new) plantings can be included to correct existing conditions by “filling in” the spaces between the existing plants where mowing is difficult or not possible. Living snowfences, wildflowers or “deer reflectors” may also be included in this zone. All new planting in this zone shall be carefully coordinated with NYSDOT Maintenance to insure that it can be maintained without undue effort. Any exceptions to this rule must be agreed to by NYSDOT Maintenance.

Any dead and/or dying trees should be carefully reviewed for potential hazards. If it is determined that the tree would not cause a hazard if it falls, consideration should be made to leave the tree standing. Dead trees provide cover, nesting cavities and perches for birds and small animals.

Vegetation management practices may be modified depending on the characteristics of the land use adjacent to the corridor (urban, suburban, and rural). Urban corridors may be expected to have a greater proportion of High Management and Frequently Mowed vs. Annually and No-Mow Zones. Additionally, parkways and expressways may require different management due to the nature of the different roads.

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## **IMPACTS OF HIGHWAYS ON DUTCH BREEDING BIRDS: AN ANALYSIS BY APPLYING NATIONAL BIRD CENSUSES**

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**Abstract** Field studies under controlled circumstances have demonstrated adverse impacts of highways on breeding birds. These studies show that the presence and use of highways deteriorates habitat quality of a selected number of breeding birds from forests and wet meadow birds, resulting in lower population densities along roads. Studies showing effects on the national population level, however, are not available.

The project aimed to describe impacts of highways on the population level for a wide variety of breeding birds in the Netherlands. During the last twenty years, SOVON - being a non-governmental organization - has built up enormous data on the distribution and numbers of Dutch breeding birds. Also plots were monitored yearly on the presence of breeding birds during a considerable period of time. The availability of these data addressed the question whether the increase in the Dutch highway length and traffic intensity that took place from 1975 to 2000, has led to significant changes in the distribution of breeding birds. In contrast with other studies, the SOVON data allow us to address a large number of bird species in a broad range of habitat types.

### **Funding Source and Total Budget**

The project was funded by the Dutch Ministry of Transport, Public Works and Water Management, The Netherlands. The research was carried for the amount of \$120,000 U.S. dollars.

### **Analyses and Results: Summary**

Analyses were based on the assumption that changes in figures of species relate directly to the presence and changes in the highway's length and highway's traffic intensity. It was also assumed that the most predictive parameters for breeding bird presence and densities are addressed by the type of habitat and the geographic region. From other studies it was concluded that traffic noise appears to be a good predictor of the traffic's influence, and threshold values were derived for so-called "effect zones," depending on traffic and road characteristics. These effect zones along roads were used as an indicator for the areas along roads with an expected impact from traffic.

To assess how many breeding bird species were affected by road traffic, data were used from hundreds of survey plots counted yearly between 1984 and 2000; two national surveys on distribution, 1973-1977 (5x5km basis) and 1998-2000 (1x1 and 5x5 basis); and the national survey on rare breeding birds (1x1km basis). For 125 breeding bird species, analyses based on one or more of these data sets could be conducted. Negative impacts for traffic (e.g., effects on density and or presence/absence) could be shown for 25-50 percent of the species, depending on the type of analysis. An integration of these results shows that for more than 50 percent of the species the highway's impact is negative. These effects appear in all kinds of habitats, the largest proportion of affected species is found for those of heath land and marshland habitats, the lowest proportion for species of (sub)urban and rural habitats. The effects are spread over a wide variety of taxonomic groups. Species of special conservation concern (on the Dutch Red List or EU- Bird Directive) showed larger negative impacts than average. In 11 percent of the species a positive effect was found, mainly for species of (sub)urban and rural habitats. This probably is related to small habitat changes associated with road presence that could not be taken into account in the analyses and that work out positive for species of open habitats, e.g., presence of broad ditches along highways.

### **Implication for Further Research/Policy Development**

The obtained results are in accordance with Dutch empirical research which was conducted in the mid 90's on a restricted number of plots of grasslands and woodland. The Directorate-General of Public Works and Water Management may use these results for emphasizing dose-impact responses on breeding birds into environmental impacts assessment (EIA) studies, and for considering a more reserved approach towards new development in vulnerable habitats, such as woodlands and marches.

The project results legitimize further research into the impacts of highway development in or near the vicinity of areas that are protected by the European Bird Directive and the National Ecological Network. Additionally, the results stress that we should know more in detail about the effectiveness of mitigation measures that reduce ecological impacts, such as noise screens and sound-suppressing concrete asphalt, in order to preserve the habitats that are important from the avian point of view.

**Website:** [www.sovon.nl](http://www.sovon.nl)

## **INVERTEBRATES – A FORGOTTEN GROUP OF ANIMALS IN INFRASTRUCTURE PLANNING? BUTTERFLIES AS TOOLS AND MODEL ORGANISMS IN SWEDEN**

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**Abstract:** There is a growing concern about the ecological effects of roads and railways on animals. There is increased mortality due to road kills, changes in movement patterns and changes in the physical environment in areas affected by infrastructure. A majority of all studies have been on larger mammals. There are also a growing number of studies on smaller animals like birds, amphibians and small mammals. However, the studies of invertebrates are few in comparison with vertebrates, and the knowledge of the effects of infrastructure on this group is limited. The importance of also including invertebrates in the studies of infrastructure is evident. First of all, this group of animals is the richest of species that exists. They are also ecologically important. In Sweden, a majority of the red-listed species are invertebrates. Of 4,120 red-listed species, fully 2,337 are invertebrates. Their generation times are fast, which also makes the response on changes in their environment fast, compared to mammals and birds. For that reason, invertebrates can be expected to give an indication earlier than mammals if an area is negatively affected by infrastructure.

Butterflies have several traits that make them suitable as model organisms to represent the invertebrates when studying problems due to infrastructure. In Sweden, they inhabit one of the most species-rich habitats: floral-rich semi-natural grasslands and open deciduous forests. This habitat has decreased 82 percent since 1880. Today it contains more than 1,000 red-listed species in Sweden. The habitat is sensitive to further fragmentation due to effects of infrastructure. There is a need to identify species that are dependent on these landscapes and that are possible to monitor. Butterflies are good candidates. It is relatively easy and cheap to catch and mark a large number of butterflies. They are active in daytime, and it is easy to put marks on their wings with simple equipment. Since some butterfly species are sensitive to habitat fragmentation and occur in species-rich habitats they may act as indicators of biologically rich landscapes and, therefore, as model organisms in infrastructure planning. Many butterflies are dependent on systems of patches, and that contact between them and the area of the patches are key elements in the preservation.

In one study we examined the changes in the butterfly fauna across a gradient from an intensively managed agricultural landscape with a large amount of open fields to a landscape rich in semi-natural grasslands and deciduous forests. The study took place in the province of Östergötland in southeast of Sweden. About 70 percent of the species showed a positive response to the amount of semi-natural grasslands and open deciduous forests in the landscape. More species showed a significant response at the landscape level compared to at the site-level (e.g., site area).

There seems to be clear thresholds in area demands where a small increase in the amount of habitats has large effect on occupancy probability. If you look at single species, the value for 50 percent probability of occurrence varied between 3-10 percent grasslands and deciduous forests for the seven species where the landscape factor was positively significant. For these species, there was a sharp drop in probability of occurrence at the thresholds. The individual species and groups of species that show clear thresholds in area demands can be used as indicators of biologically rich landscapes. In this study the whole group of the family Zygaenidae and the fritillaries may be used as indicators.

In another study we investigated the barrier effect by marking and recapturing butterflies along the motorway E4 in southeast Sweden. The motorway was surrounded by semi-natural pastures with portions of deciduous trees on both sides. Every capture of an individual was positioned by GPS, and by plotting the data in a GIS application we could analyze the dispersal ability and the flight direction of most of the species. The results showed that there were large differences between species regarding the dispersal ability. We used the data set to simulate a new data set of random movements. For the Ringlet (*Aphantopus hyperantus*) we expected 12 percent crossings of the motorway but (we) found only 3 percent in our field data. The barrier effect was therefore calculated to 75 percent for the Ringlet. The migratory species Green-veined white (*Pieris napi*) showed another pattern, and we both expected and found 14 percent crossings.

The main conclusions from this study of using butterflies in the planning process are:

- Butterflies can be used to identify rich landscapes.
- There exist critical thresholds, and infrastructure has probably the largest impact around the thresholds (3-10% of natural habitat left).
- Indicator species may be used to identify rich landscapes.
- Roads may act as barriers to some species.
- Invertebrates are a significant group to consider in infrastructure planning.

In the future the results can be used to identify potentially species rich areas without expensive field surveys, before the start of road and railway projects. Using data from aerial photos or satellites and analyzing them with thresholds for groups of species in a GIS application could give us a tool to prevent further fragmentation by infrastructure. The development of this tool is the next challenge, but there is also a need to confirm our findings in other landscapes as well. The thresholds in this study should be interpreted with some caution as the landscapes around some sites sometimes overlap each other.



Fig. 1. Semi-natural grasslands are one of the most species-rich habitats in Sweden with more than 1,000 red-listed species.

## **Introduction**

There is a growing concern about the ecological effects of roads and railways on animals. For example, based on road-effect zones, an estimated 15-22 percent of the United States is ecologically impacted by roads (Forman 2000, Forman and Alexander 1998). A number of negative effects of roads and railways have been indicated. Among others, there is increased mortality due to road kills, changes in movement patterns and changes in the physical environment in areas affected by infrastructure (Trombulak and Frissell 2000). A majority of all studies have been on larger mammals, e.g., road kills of moose (*Alces alces*), negative effects of roads on the distribution on elephants (*Loxodonta africana*) in Gabon (Barnes and others 1991) and threshold effects of road density on wolves (*Canis lupus*) (Mech 1989). There is also a growing number of studies on smaller animals like birds, amphibians and small mammals (Trombulak and Frissell 2000). However, the studies of invertebrates are few in comparison with vertebrates, and the knowledge of the effects of infrastructure on this group is limited.

## **Why Study Invertebrates?**

There are a number of reasons why the studies of infrastructure effects also should include invertebrates. First, they are the most species-rich group of animals that we have. Insects alone comprise more than 80 percent of the estimated number of species on earth (Samways 1993). They are also ecologically important. Insects constitute an indispensable part of many food chains, do nutrient recycling, provide us with model organisms in science (e.g., *Drosophila melanogaster*) and have a major role in plant pollination. Pollination is estimated to be worth US\$1.6-5.7 billion annually in the U.S. alone (Gullan and Cranston 1994).

In Sweden, a majority of the red-listed species are invertebrates. Of 4,120 red-listed species, fully 2,337 are invertebrates (Gärdenfors 2000). Many of the invertebrate species also use the landscape in the same scale as infrastructure affects the landscape. Populations of threatened invertebrates often exist in small areas, and a road construction may eradicate the whole habitat and population. Some of the species have a low dispersal ability ranging in hundreds of meters, and if the road acts as a barrier, populations may lose contact with each other. Inbreeding and reduced colonization rate may then be the result of road constructions. Their generation times are fast which makes the response to changes in their environment fast compared to mammals and birds. For that reason, invertebrates may give an indication earlier than mammals if an area is negatively affected by infrastructure.

## **Butterflies and Infrastructure**

Butterflies have several traits that make them suitable as model organisms to represent the invertebrates when studying problems due to infrastructure. In Sweden, they inhabit one of the most species-rich habitats: floral-rich semi-natural grasslands (fig. 1) and open deciduous forests. The reason for the richness of species of this habitat is probably that it is a remnant of a very old half-open, park-like ecosystem, formed by now extinct herbivores (Vera 2000). Among others, large grazers like aurochs and tarpans created a park-like landscape with a very high diversity of biotopes and a rich animal life. The remnant of this flora and fauna now survives in unfertilised semi-natural pastures managed by farmers and grazing animals, domesticated forms of aurochs and tarpans. This habitat has decreased 82 percent since 1880 (Angelstam and others 1993). Today it contains more than 1,000 red-listed species in Sweden.

The habitat is sensitive to further fragmentation due to effects of, e.g., infrastructure. There is a need to identify species that are dependent on these landscapes and that are possible to monitor. Butterflies are good candidates. Several studies have shown that butterflies are dependent on systems of patches, and that contact between them and the area of the patches are key elements in the preservation of butterflies

(Thomas and Hanski 1997). The same is probably true for most other invertebrate species. One obvious effect of infrastructure is that whole patches and populations may disappear due to the construction work, but as the habitat semi-natural grasslands is dependent on grazing to maintain its diversity, in the long run, other effects also occur. A large road in a system of semi-natural grasslands may make it very difficult for a farmer to transport animals between the patches. As a result, some of the patches are often abandoned, and the park-like grassland slowly transforms to forests, and much of the flora and fauna goes extinct during the succession. Many butterfly species react quickly on succession. A review of 22 detailed studies of butterflies concluded that in 20 of them butterflies were sensitive to successional changes (Bergman 2001). Most of the reported local extinctions of butterfly populations in Britain have been due to successional changes that arose upon cessation of management (Bergman 2001). Recently, a three mile stretch of a large road in Britain was totally removed and replaced by a footpath to be able to graze one 400 ha patch that harbours one of the last large populations of the threatened march fritillary (*Euphydryas aurinia*) (BBC Wildlife 2001).

Alternation of movements and population densities is another possible negative effect of infrastructure. There exist many studies of how infrastructure affects mammal density and movements, but there are few studies of invertebrates. Roads were effective barriers of movement for carabid beetles and spiders in a study in Germany (Mader 1984, Mader et al. 1990). Also flying invertebrates may be affected. A motorway (c. 50m wide) in Britain reduced the flow of individuals of the butterfly *Antocharis cardamine* by 91.8 percent (Dennis 1986). Mungiura and Thomas (1992) found smaller effects on butterfly movements near smaller roads. However, there were significantly fewer crossings than predicted assuming random movements.

No studies have so far been made to our knowledge about how the barrier effect may affect population survival in the long term for invertebrates. This kind of research is often time- and money-consuming. However, it is relatively easy and cheap to catch and mark a large number of butterflies. They are active in daytime, and it is easy to put marks on their wings with simple equipment. Since some butterfly species are sensitive to habitat fragmentation and occur in species-rich habitats they may act as indicators of biologically rich landscapes and therefore as model organisms in infrastructure planning.

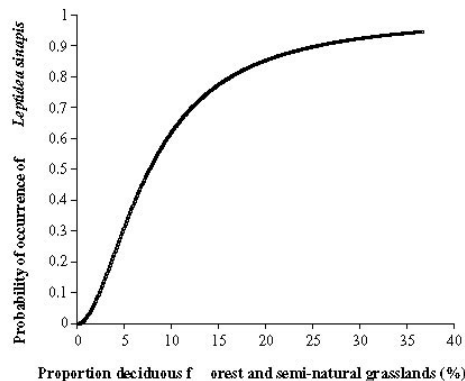


Fig. 2. The probability to find the butterfly *Leptidea sinapis* in a single site as a function of the proportion of semi-natural grasslands and deciduous forests in the surrounding landscape (a circle around the site with a diameter of 5km).

### **Butterflies as Landscape Indicators**

One of the main aims of our studies was to investigate the possibility to identify landscapes with semi-natural grasslands and open deciduous forests of high conservation interest by using butterflies. We set up a study where we examined the changes in the butterfly fauna across a gradient from an intensively managed agricultural landscape with a large amount of open fields to a landscape rich of semi-natural grasslands and deciduous forests. We also analyzed the effects of the surrounding landscape on the butterfly community at different scales. The study was carried out in the province of Östergötland in the southeast of Sweden. The distribution of potential butterfly habitats was identified through interpretation of infrared aerial photos. In total the study covered about 1,750km<sup>2</sup>. A total of 12,824 areas were identified and butterflies were recorded in 62 of these sites. The 62 sites consisted of open to half-open semi-natural grasslands with at least 30 percent of the site area unfertilized since oligotrophic unfertilized areas support the richest flora.

In total, 12,179 butterfly individuals of 57 species were observed on the 62 sites. An analysis of the data showed that a total area of open deciduous forests and semi-natural grasslands with a tree and bush cover greater than 25 percent in the landscape was important for the species diversity of butterflies. The area of grasslands and deciduous forests in 5000m from the studied butterfly site had a significant positive effect on

both species richness and occurrence of single species. The areas in 500m and 2000m were not as important. Therefore, our study indicates that a relevant scale to predict the occurrence of species richness of butterflies in a certain site, is to study the occurrence of suitable habitats 5km from the site.

About 70 percent of the species showed a positive response to the amount of semi-natural grasslands and open deciduous forests. Furthermore, it was more relevant to analyze species occurrences at the landscape level than the site-level (e.g., site area). Species showing negative correspondence of grasslands and deciduous forests are known migratory species utilizing man-made habitats as the Small white *Pieris rapae* and Small tortoiseshell *Aglais urticae*.

There seems to be clear thresholds in area demands where a small increase in the amount of habitat has a large effect on occupancy probability. One example of using butterflies as landscape indicators can be to look for all areas that have a probability above 50 percent to harbor greater than 20 species. Our results show that a single site has a 50 percent chance to harbor greater than 20 species in landscapes with proportions of more than 7 percent habitat area. If you look at single species, the value for 50 percent probability of occurrence varied between 3-10 percent grasslands and deciduous forests for the seven species where the landscape factor was positively significant. For these species, there was a sharp drop in probability of occurrence at the thresholds (fig. 2). This means that for successful conservation, it is important to identify landscapes above the threshold in the planning process of infrastructure.

Individual species and groups of species that show clear thresholds in area demands can be used as indicators of biologically rich landscapes, instead of studying a large number of species that may need expensive expertise. One group of demanding species seems to be the whole family Zygaenidae. For a site to harbor at least one species of Zygaenidae, there has to be greater than 5.2 percent of grasslands and deciduous forests. Some other indicator species seem to be the whole group of fritillaries and especially *Mellicta athalia*, *Boloria selene*, *B. euphrosyne* (Nymphalidae and *Heodes virgaureae*, (Lycaenidae). These species have in common low dispersal abilities and host plants from oligotrophic habitats.

### **Barrier Effects**

Another important factor regarding infrastructure is the barrier effect. Even if it is possible to avoid suitable habitats when planning for infrastructure and even if the total area affected is small, there can be problems for species to survive in the long term. If populations lose contact between each other due to the barrier effect of the road, recolonisations after extinctions may be greatly delayed. The populations may in the long run go extinct on both sides of the road if the fragment on each side is too small to exist without the help of migrating individuals. To investigate the impact on dispersal, the barrier effect, of a road we marked and recaptured butterflies along the motorway E4 in the southeast Sweden near the border of the provinces of Östergötland and Jönköping (fig. 3). The motorway was surrounded by semi-natural pastures with deciduous trees on both sides. The habitat was considered suitable and with small differences on both sides.



Fig. 3. Study site for the mark-release-recapture work.  
A motorway intersects a species-rich semi-natural grassland.

The results showed that all species were found on both sides. Every capture of an individual were positioned by GPS and a total of 8,415 individuals of 55 species were marked and recaptured. By plotting the data in a GIS application we could analyze the dispersal ability and the flight direction of the species (fig. 4). The results

show that there were large differences between species regarding their dispersal ability. Some species like *Pieris napi* and *Gonepteryx rhamni* (Pieridae) crossed the road relatively often. However, some species like *Coenonympha arcania*, *Aphantopus hyperantus* (Nymphalidae) and *Polyommatus semiargus* (Lycaneidae) seldom crossed the road in spite of large populations on both sides of the road.

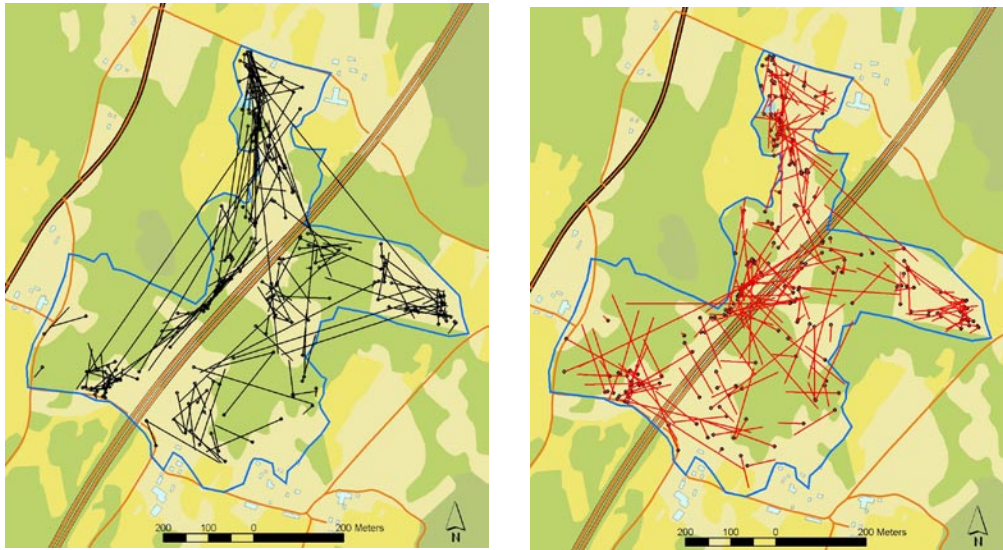


Fig. 4. The dispersal and crossings over a motorway of the Ringlet (*Aphantopus hyperantus*) in semi-natural pastures surrounding the motorway E4 southeast of Sweden. The black lines (left image) are real data from the mark-release-recapture study and the red lines (right image) are a random simulation of the same data set.

We used the data set to simulate a new data set of random movements based on the found pattern of dispersal distances for each species but with random angles in each movement. For the Ringlet (*Aphantopus hyperantus*) we expected 12 percent crossings of the motorway but we observed only 3 percent in our field data (fig. 4). The barrier effect was therefore calculated at 75 percent for the Ringlet. The migratory species Green-veined white (*Pieris napi*) showed another pattern, and there were no differences between expected and observed crossings (14% in both cases). For this species we could not estimate any barrier effect. This indicates that roads may act as barriers also to flying insects, but that it may be species specific, and that careful planning may be needed for keeping the contact between populations even though the butterfly sites themselves are untouched.

### **A Hypothetical Example of Infrastructure Effects**

A hypothetical example may shed light upon the difficulties in infrastructure planning and invertebrate conservation. From the beginning (A) there is a system of patches of semi-natural grasslands forming a metapopulation for several butterfly species (fig. 5). The existence of the meta-population is balanced by local extinctions and colonization's among the local populations. In the planning process each site is identified and a road is planned to avoid the sites (B). When the road is built (after building of the road) populations go extinct in the smaller patches south of the road (blue-crossed markings) as a consequence of the barrier effect of the road, because migrating animals from other populations cannot recolonize the areas. In the long run, the whole meta-populations north of the road may also go extinct, because the number of sites is now only six and nine on each side of the road, and the total area on each side is no longer enough to maintain the system – an important threshold has been passed. Field data indicate that butterfly meta-populations living in systems with less than 15-20 patches are very sensitive to further loss of patches (Thomas and Hanski 1997).

The example above shows how fragmentation of natural habitats could cause extinctions, but most important is that the severe effects of fragmentation can be avoided if knowledge of population processes is introduced in the planning process.

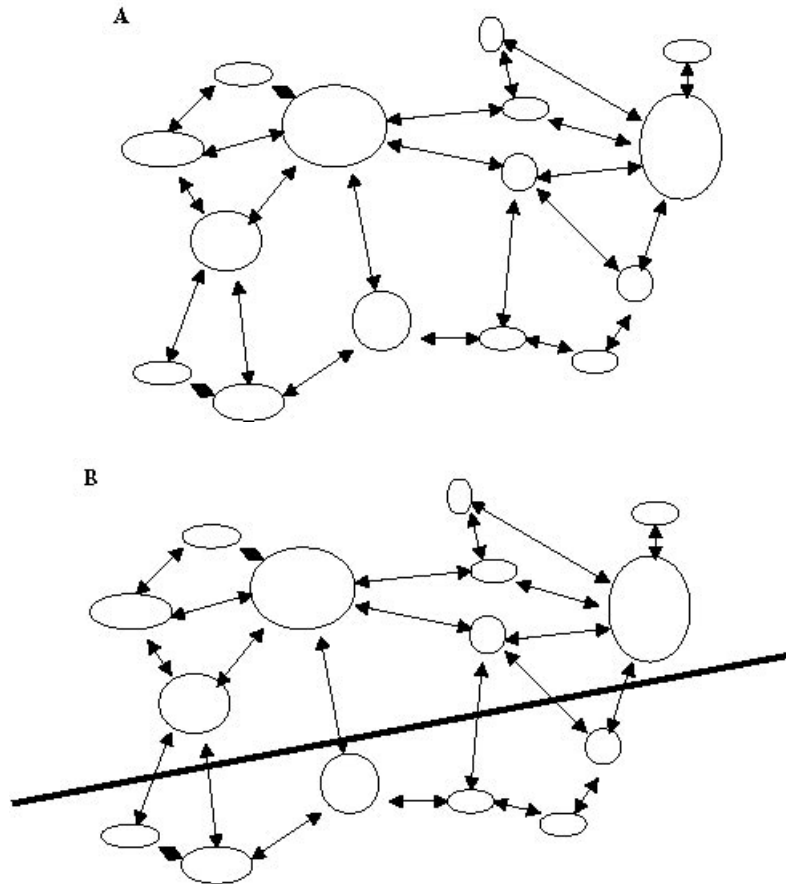


Fig. 5. A hypothetical example of a meta-population in balance between extinctions and colonizations where the populations in the different patches have just enough contact with each other to exist in the long term. A road may in the long run cause the extinction of the whole meta-population.

### **Conclusions of Using Butterflies in the Planning Process**

In this study we have focused on invertebrates in general and butterflies in particular to investigate if they are a possible object to study in open to half-open habitats with high conservation values. Our main conclusions, so far, are:

- Butterflies can be used to identify rich landscapes.
- There exist critical thresholds, and infrastructure has probably the largest impact around the thresholds (3-10% of natural habitat left).
- Indicator species may be used to identify rich landscapes.
- Roads may act as barriers to some species.
- Invertebrates is a significant group to consider in infrastructure planning.

In the future the results can be used to identify potentially species-rich areas without expensive field surveys, before the start of road and railway projects. Using data from aerial photos or satellites and analyzing them with thresholds for groups of species in a GIS application could provide a tool to prevent further fragmentation by infrastructure. The development of this tool is a challenge, but there is also a need to confirm our findings in other landscapes as well. The thresholds in this study should be interpreted with some caution as the landscape around some sites overlaps.

**Biographical Sketch:** John Askling received his Bsc in biology in 1995 after studying at the Universities in Linköping and Lund. From 1992 he was a research assistant until 1996 in a project concerning butterfly communities in semi-natural grasslands. In 1992 he also was one of the founders of CALLUNA AB, which is a conservation consultancy corporation. Since 2001 he has been is the CEO of the company. At CALLUNA he has worked with many projects concerning infrastructure and the environmental impact assessment belonging to the planning process. He and CALLUNA have a special interest in making ecology applicable in infrastructure projects. Therefore he is taking part in the research project "Landscape ecological effects on invertebrates of roads and railways" in collaboration with Linköping University. The aim of the project is to study landscape ecological effects of roads and railways on invertebrates. The Swedish National Road Administration and the Swedish National Railroad Administration fund the project.

Karl-Olof Bergman received his BSc in biology in 1990 after courses at Linköping University. He moved on to do a PhD (2000) in conservation biology with the threatened butterfly *Lopinga achine* as a model organism along with teaching biology. *Lopinga achine* is included on the list of endangered flora and fauna compiled by the Bern Convention and in the EU Habitats Directive. He is now a lecturer and a researcher in conservation biology at Linköping University. His research includes the project "Landscape ecological effects on invertebrates of roads and railways" in collaboration with CALLUNA AB. The aim of the project is to study landscape ecological effects of roads and railways on invertebrates. The Swedish National Road Administration and the Swedish National Railroad Administration fund the project. He has also developed monitoring methods for insects for the Swedish Environmental Protection Agency and done research on population viability analysis of *Lopinga achine*.

## References

- Angelstam, P., S. Danell, L. Kautsky, N. Kautsky, L-E. Liljelund, P-E. Lingdell, and M. Löfroth. *Biologisk mångfald. Miljön i Sverige - tillstånd och trender*, eds. M. O. G. Eriksson and L. Hedlund. Värnamo: Naturvårdsverket, 1993.
- Barnes, R. F. W., K. L. Barnes, M. P. T. Alers, and A. Blom. "Man determines the distribution of elephants in the rain forests of north-eastern Gabon." *African Journal of Ecology* 29 (1991): 54-63.
- Bergman, K-O. "Population dynamics and the importance of habitat management for conservation of the butterfly *Lopinga achine*." *Journal of Applied Ecology* 38 (2001): 1303-1313.
- BBC Wildlife 2001. October issue.
- Dennis, R. L. H. "Motorways and cross-movements. An insect's 'mental' map of the M56 in Cheshire." *Bulletin of the Amateur Entomologists' Society* 45 (1986): 228-243.
- Forman, R. T. T. "Estimate of the area affected ecologically by the road system of the United States." *Conservation Biology* 14 (2000): 31-35.
- Forman, R. T. T. and L. E. Alexander. "Roads and their major ecological effect." *Annual Review of Ecology and Systematics* 29 (1998): 207-231.
- Gullan, P. J. and P. S. Cranston. *The insects. An outline of entomology*. London: Chapman & Hall, 1994.
- Gärdenfors, U., ed. *The 2000 Red List of Swedish Species*. Uppsala: ArtDatabanken, 2000.
- Mader, H-J. "Animal habitat isolation by roads and agricultural fields." *Biological Conservation* 29 (1984):81-96.
- Mader, H-J., C. Schel, and P. Kornacker. "Linear barriers to arthropod movements in the landscape." *Biological Conservation* 54 (1990): 209-222.
- Mech, L. D. "Wolf population survival in an area of high road density." *Am. Midl. Nat.* 121 (1989): 387-389.
- Mungiura, M. L. and J. A. Thomas. "Use of road verges by butterfly and burnet populations, and the effect of roads on adult dispersal and mortality." *Journal of Applied Ecology* 29 (1992): 316-329.
- Samways, M. J. "Insects in biodiversity conservation: some perspectives and directives." *Biodiversity and Conservation* 2 (1993): 258-282.
- Thomas, C. D. and I. Hanski. "Butterfly metapopulations." In *Metapopulation biology: ecology, genetics and evolution*, eds. I. Hanski and M. E. Gilpin. 359-386. San Diego: Academic Press, 1997.
- Trombulak, S. C. and C. A. Frissell. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology* 14 (2000): 18-30.
- Vera, F. W. M. *Grazing ecology and forest history*. Wallingford: CABI International, 2000.