Annex 3

Record of Scientific Achievement

Dr Dawid Moroń

Institute of Systematics and Evolution of Animals

Polish Academy of Sciences

Kraków 2018

1. Name.

Dawid Moroń

2. Diplomas and academic degrees, with title of work, and place and year.

2009	doctor of biological sciences, Jagiellonian University. Title: "The impact of heavy metal pollution on mason bees (*Osmia rufa* L.) and the diversity of other wild bees". Promoter: Prof Dr Hab Michał Woyciechowski.
2003	master of biology, Jagiellonian University. Title: "Effect of the expected life expectancy on the division of labour in European fire ants (*Myrmica rubra L.*)". Promoter: Prof Dr Hab Michał Woyciechowski.

3. Information on earlier work in scientific departments.

X 2013 – III 2016	intern (post-doctoral), Poznań University of Life Sciences.
I 2008 – present	researcher, Institute of Systematics and the Evolution of Animals, PAN, Kraków.
X 2003 – IX 2007	independent biologist, Institute of Environmental Sciences, Jagiellonian University, Kraków.

4. Indication of the achievement in accordance with Art. 16, Sec. 2 of the Act of 14 March 2003 on Academic Degrees and Academic Titles and on Degrees and Titles in the Field of Art (Journal of Laws No. 65, Item 595, as amended).

4A. Title of scientific achievement.

New habitats: an opportunity for pollinating insects?

4B. Papers forming part of this scientific achievement. Impact factor (IF) shown according to year of publication (for publications from 2018, IF from 2017). MNiSW points cover the harmonised list of scientific journals for the years 2013-2016.

Moroń D., Skórka P., Lenda M., Rożej-Pabijan E., Wantuch M., Kajzer-Bonk J., Celary W., Mielczarek Ł.E., Tryjanowski P. 2014. Railway embankments as new habitat for pollinators in an agricultural landscape. PLoS ONE 9: e101297. DOI: 10.1371/journal.pone.0101297. (IF_{2014} = 3,234; MNiSW = 40)

Moroń D., Skórka P., Lenda M., Celary W., Tryjanowski P. 2017. Railway lines affect spatial turnover of pollinator communities in an agricultural landscape. Diversity and Distributions, 23: 190-197. DOI: 10.1111/ddi.12600 (IF_{2017} = 4,614; MNiSW = 45)

Moroń D., Przybyłowicz Ł., Nobis M., Nobis A., Klichowska E., Lenda M., Skórka P., Tryjanowski P. 2017. Do levees support diversity and affect spatial turnover of communities in plant-herbivore systems in an urban landscape? Ecological Engineering, 105: 198-204. DOI: 10.1016/j.ecoleng.2017.04.052. (IF_{2017} = 3,023; MNiSW = 35)

Moroń D., Skórka P., Lenda M., Kajzer-Bonk J., Mielczarek Ł., Rożej-Pabijane E., Wantuch M. 2018. Linear and non-linear effects of goldenrod invasions on native pollinator and plant populations. Biological Invasions. DOI: 10.1007/s10530-018-1874-1. (IF_{2017} = 3,054; MNiSW = 35)

Moroń D., Skórka P., Lenda M. 2018. Disappearing edge: the flowering period changes the distribution of insect pollinators in invasive goldenrod patches. Insect Conservation and Diversity. DOI: 10.1111/icad.12305. (IF_{2017} = 2,091; MNiSW = 40)

4C. Total Impact Factor for year of publication.

16,016

4D. Total number of MNiSW points (according to harmonised list of scientific journals).

195

4E. Discussion of the scientific goals of the work, the results achieved, and their potential application.

Habitats differing in structure and function from those of the past, and existing now, are called novel/emerging/no-analogue habitats/ecosystems.[1] New habitats arise as a consequence of, for example, changes taking place in the landscape or in the distribution of organisms. Changes in landscape use, including the creation of new structures by people, result mainly from the expansion of infrastructure, or from urbanisation. Changes in the range of species, including the formation of homogeneous communities, are a result of the globalisation of trade or climate change. These large-scale processes, being a direct or indirect effect of human activity, are responsible for creating habitats with new characteristics. Although all habitats can be considered as new if they are placed in the right time context, the emergence of new habitats and their diversity in the Anthropocene is much more diverse compared to previous periods.[1]

[1] Hobbs R.J., Higgs E.S., Hall C.M. 2014. Novel ecosystems: intervening in the new ecological world order. John Wiley & Sons, Chichester, UK.

In order to conserve nature in a globalised world, the most valuable natural sites, being the remains of natural or semi-natural habitats, are protected. Although protection of (semi)natural areas is a necessity, it seems also to be the form of protection which is, in practice, the most difficult to implement. The financial costs associated with this type of protection, and conflicts with local communities, very often make it impossible to implement fully the goals of species and habitat conservation. Finding an alternative to protecting semi-natural habitats is therefore crucial for nature conservation. Such an alternative may be the use of habitats that are the result of direct or indirect human activity, especially in landscapes strongly transformed by humans.

Plant pollination by animals plays a key role in maintaining high biodiversity, and is one of the most important ecosystem services. In the temperate climate zone, the most important pollinating organisms are insects (bees, butterflies and flies). It is estimated that 78% of wild plant species in the temperate zone are pollinated by these animals. At the same time, animals pollinate crops whose yields are worth around EUR 14 billion per year, in the European Union alone. Therefore, pollinating organisms can be considered as a key group for the functioning of natural habitats as well as those greatly altered by humans. Unfortunately, populations of pollinating insects are now seriously endangered, mainly due to the disappearance and fragmentation of habitats. Hence the need to protect pollinating insects and their habitats, especially in landscape transformed by humans, where negative factors can be particularly intense.

Therefore, the question is whether new habitats can significantly support the protection of biodiversity and ecological processes while maintaining ecosystem services at an appropriate level. The works presented below try to answer the above question.

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Moroń D., Skórka P., Lenda M., Rożej-Pabijan E., Wantuch M., Kajzer-Bonk J., Celary W., Mielczarek Ł.E., Tryjanowski P. 2014. Railway embankments as new habitat for pollinators in an agricultural landscape. PLoS ONE 9: e101297. DOI: 10.1371/journal.pone.0101297.

Railway lines with embankments are elements of infrastructure commonly occurring in a landscape strongly changed by humans. The European Union and the United States each have about 200,000 Km of railway lines. Due to their specific structure (dry and well sunlit on top, with cool, damp foundations), railway embankments are associated with strong diversity of environmental conditions. This can create the right conditions for many plant species and pollinating insects. On the other hand, it is necessary to establish whether railway traffic and the accompanying use of embankments create conditions unsuitable for many species of pollinating insects.

In order to establish whether the new habitat created by railway embankments in the agricultural landscape is valuable for pollinating insects (bees, butterflies and flies), we carried out field research. First, we checked whether railway embankments are characterised by a higher level of biodiversity compared to the habitat typical for pollinating insects in the agricultural landscape, that is, extensively used meadows. Second, we defined the characteristics of railway embankments that affect the diversity of pollinators. It turned out that the number of species and individuals was about 30% (bees) and 45% (butterflies) higher on railway embankments than on control meadows. Differences in the number of hoverfly species and individuals (the most effective pollinators among dipterans) on railway embankments and in meadows were negligible. In the case of railway embankments, the presence of open soil, i.e. that uncovered plants, had a positive effect on the number of bee species and individuals, and negatively influenced the number of butterfly species and individuals. In turn, the number of species of native plants growing on embankments positively influenced the number of butterfly species and individuals, while the number of alien plants positively influenced the number of bee species. As the coverage of embankments by bushes and trees increased, the number of bee species and individuals decreased. The number of bee and hoverfly species increased with increasing coverage of the immediate vicinity of embankments (a 200-metre buffer) by forest.

The research confirms that railway embankments, as new habitats, are characterised by a high diversity of pollinating insects. Therefore, railway embankments can be considered as a substitute for (semi)natural habitats, especially in landscape such as agricultural areas which have been greatly altered. Interestingly, railway embankments, regardless of their height and inclination, are equally valuable for pollinating insects. The features of the landscape immediately surrounding the embankments do not have a significant impact on pollinating insects on railway embankments. These results indicate that the majority of railway embankments in agricultural landscapes usually serve as valuable habitats for pollinating insects.

Moroń D., Skórka P., Lenda M., Celary W., Tryjanowski P. 2017. Railway lines affect spatial turnover of pollinator communities in an agricultural landscape. Diversity and Distributions, 23: 190-197. DOI: 10.1111/ddi.12600

In order for a new habitat to function as a substitute for (semi)natural areas in a landscape that has been greatly transformed, it is important not only to maintain high biodiversity, but also to ensure communication between populations. This is important because fragmentation of habitats is one of the most important factors responsible for the decline of biodiversity in areas with landscapes that have been altered significantly as a result of human activity. Unfavourable transformation of the landscape most often increases the area (matrix), which is not conducive, at least for some species, to completing the life cycle and to movement, in comparison to areas not transformed by humans.[2] New habitats often arise in areas with a high proportion of matrices, for example in agricultural or urban landscapes, can increase communication between populations while reducing the negative effects of habitat fragmentation. In particular, new habitats with linear landscape elements, such as railway embankments, can act as ecological corridors mitigating the effects of habitat fragmentation.

Species differ in biological traits, and this affects the efficiency of movement. Body size is one such feature, as larger species tend to have greater dispersion capabilities and can

[2] Ricketts T.H. 2001. The matrix matters: Effective isolation in fragmented landscapes. The American Naturalist, 158, 87-99.

overcome greater distances than species with smaller body sizes. Another biological trait related indirectly to dispersibility is food specialisation. It is believed that, for species with narrow food specialisation, as in the case of pollinating insects using several species of plants, the landscape is more fragmented, meaning the proportion of matrices is greater, compared to species with a broad food spectrum. In the conducted field tests, we examined whether new habitats such as railway embankments support communication between populations of pollinating insects (bees, butterflies and flies) depending on their body size and food specialisation. To this end, we compared the differences in species composition of pollinating insects found on railway embankments according to the geographical distance between embankments. In the same way, we compared the populations of pollinating insects found in control meadows, being at least 1 kilometre from the nearest railway lines. We predicted that, in the case of communication between populations, the diversity of species composition would correlate positively with the distance between research areas, so that species composition of populations located at a lesser distance would be more similar compared to more distant populations. It turned out that the differences in species composition have a positive relationship with the distance between the research areas in the case of bees with a wide spectrum of food. Populations of butterflies and hoverflies of large body size also demonstrated a positive relationship between the diversity of species composition and the distance between research areas. Significant relationships between diversity of species composition and distance between research areas were not found in control meadows, which suggests that differences in species composition in populations between control meadows result from factors other than dispersal of individuals, for example from random or environmental factors.

Our research indicates that railway embankments increase communication between populations, at least for pollinators with larger body sizes and less food specialisation. In counteracting the negative effects of landscape transformations, railway embankments are not only habitats that maintain diverse and numerous populations of pollinating insects, but also should be taken into account when designing ecological corridors. A well-designed network of ecological corridors can significantly increase the intensity of spatial ecological processes concerning the distribution of pollinating insects in landscapes that have been altered significantly by humans. Our research shows that railway embankments are examples of man-made structures which meet the needs of both civilisation and nature conservation.

Moroń D., Przybyłowicz Ł., Nobis M., Nobis A., Klichowska E., Lenda M., Skórka P., Tryjanowski P. 2017. Do levees support diversity and affect spatial turnover of communities in plant-herbivore systems in an urban landscape? Ecological Engineering, 105: 198-204. DOI: 10.1016/j.ecoleng.2017.04.052

According to estimates, by 2050, the share of the population living in cities in highly developed countries will increase to over 80%, and in developing countries to over 60%. This indicates that urbanisation will continue to be one of the most serious threats to biodiversity in the world. Therefore, it is extremely important to create and support various types of biodiversity conservation plans in urban areas, and to design green zones in cities to enable basic ecological processes to take place. Because it is extremely difficult to find semi-natural habitats for protection in greatly transformed urban areas, alternative solutions are necessary.

In urbanised areas, flood embankments are a frequent feature of the landscape, and create new habitats. This is because cities were usually located in the immediate vicinity of rivers. Therefore, in order to protect life and property, many highly developed countries are expanding the network of flood embankments. For example, there are around 8,500 kilometres of flood embankments in Poland, 10,000 kilometres in France, and 40,000 kilometres in the United States. Flood embankments are characterised by a strong environmental gradient, with dry and well-lit peaks and damp, cool foundations. The diversity of habitats in a relatively small area may suggest the occurrence of conditions suitable for many species of plants and pollinating insects. However, it should be remembered that both human activity on the flood embankments (mowing) and the relatively frequent disturbances caused by river floods may lead to the creation of a new habitat poor in species. For this purpose, the hypothesis that new habitats such as flood embankments can be valuable for a diverse population of pollinating insects (butterflies) and plants in the urbanised landscape was tested. First, we checked whether flood embankments were characterised by high biodiversity compared to extensively used meadows, the habitat typical for pollinating insects and plants in the urbanised landscape. Second, we defined the characteristics of flood embankments, which determine the diversity of pollinating insects and plants. Third, in order to establish whether flood embankments can support communication between populations, we compared differences in the species composition of pollinator populations and plants along flood embankments, according to the distance between research areas. We likewise compared the populations of pollinating insects found on extensively used meadows at least 1 kilometre from the nearest flood banks, as a measure of population connectivity.

It turned out that species diversity and the abundance of butterflies occurring on flood embankments did not differ from the diversity and abundance of butterflies in control meadows. The species diversity of plants growing on flood embankments was 25% higher compared to plants in control meadows. Among the environmental features of flood embankments, the share of urban areas in the immediate vicinity (a 200-metre buffer) had a negative impact on the diversity of plants. The increase in coverage of flood embankments by shrubs and trees had a negative impact on species diversity and the number of butterflies, and the frequency of mowing on flood embankments had a negative effect on the number of butterflies. Differences in the species composition of plants growing on flood banks were positively correlated with the distance between research areas. The species composition for populations located closer was more similar than that of more distant populations. Significant relationships between the diversity of the species composition of butterflies and plants and the distance between research areas were not found in control meadows.

Our research suggests that it is possible to use infrastructure development in favour of biodiversity. This happens when new habitats, such as flood embankments and railway embankments, create successful substitute environments, performing functions that are semi-natural. We should therefore identify and manage new habitats with care, in order to protect biodiversity and important ecological processes. The management of new habitats should include, for example, appropriate mowing frequency and prevention of overgrowth by bushes and trees. The type of nature protection based on the use of new habitats should be considered of particular importance in areas heavily changed by human activity, such as in urban and agricultural areas.

Moroń D., Skórka P., Lenda M., Kajzer-Bonk J., Mielczarek Ł., Rożej-Pabijan E., Wantuch M. 2018. Linear and non-linear effects of goldenrod invasions on native pollinator and plant populations. Biological Invasions. DOI: 10.1007/s10530-018-1874-1.

New habitats are created not only as a result of direct human activity, such as the construction of railway embankments and flood embankments, but also indirectly, by the impact of humans on the environment. Among indirect changes leading to the creation of new habitats are introductions of non-native plant species. Part of an introduced plant species increases its range in the new area, most often increasing density significantly, and thus becoming an invasive species. The pressure associated with the presence of invasive plants on native biodiversity is an increasingly common phenomenon in the world.[3] Habitats dominated by invasive plants become new habitats, with features and characteristics not seen before. This is because invasive plants in high densities change not only the diversity of native species, but also the basic ecological processes occurring in the environment, such as the circulation of elements, primary production or trophic relations.

Complicated trophic relationships between plants and pollinators cause the presence of new and non-native plants to completely change the trophic system, affecting biodiversity. It is difficult to predict the impact of a new habitat created by invasive plants on the diversity of pollinating insects. This is because invasive plant species can affect pollinating insect populations both positively and negatively. In many cases, invasive plants are an additional source of food. Yet invasive species can also reduce the feeding base of pollinating insects by lowering the population of native plants. These different influences mean that we can expect two types of invasive plants to affect pollinators. The first, caused by linear dependence (most often assumed in various types of models and scenarios), suggests a definite positive or negative influence on pollinating insects. In new habitats, the variety of native plants may be greater or lesser, causing a decrease or increase in the nutrient base, mainly for food specialists. Non-linear dependence, on the other hand, indicates the predominance of negative or positive changes in the habitat from a certain critical level of invasive plant density.

Field research was carried out to determine whether a linear or non-linear scenario determines the diversity of pollinating insects in new habitats created by invasive plants. In meadows with various stages of coverage by invasive goldenrod species (coverage 0-100%), the number of species and individuals of pollinating insects (bees, butterflies and flies) was determined. The research revealed that the number and species diversity of bees and butterflies decreased non-linearly with an increase in the coverage of research areas by invasive goldenrod. Negative dependence of coverage and species diversity and abundance occurs at cover of 50% (bees) and 35% (butterflies). There were no significant dependencies

[3] Potts S.G., Biesmeijer J.C., Kremen C., Neumann P., Schweiger O., Kunin W.E. 2010. Global pollinator declines: trends, impacts and drivers. Trends in Ecology end Evolution, 25, 345-353.

between habitat coverage by the goldenrod, diversity and the number of flies. Our research also indicates that changes in the species composition of pollinating insects result from the disappearance of subsequent species along with the increase in coverage by goldenrod, rather than from the formation of new qualitative pollinator communities on habitats occupied by goldenrod.

Our work demonstrates that new habitats resulting from the invasion of alien plant species may be characterised by lower biodiversity of pollinating insects compared to meadows that are not occupied by invasive plants. Moreover, the process of invasive plants converting semi-natural habitats into new habitats may cause non-linear changes in the diversity and abundance of pollinating insects. The non-linear character of these changes probably results from influences both direct (invasive plants can be a source of food) and indirect (decrease in the diversity of native plants). When identifying and managing new habitats, the possible non-linear nature of the impact of certain features of these habitats on biodiversity should be taken into account. The negative effects of new habitats may only appear rapidly after a certain critical threshold is passed.

Moroń D., Skórka P., Lenda M. 2018. Disappearing edge: the flowering period changes the distribution of insect pollinators in invasive goldenrod patches. Insect Conservation and Diversity. DOI: 10.1111/icad.12305

To ensure that new habitats, including those created by the introduction of new species, function as substitutes for semi-natural areas, we should ensure communication between populations. As already noted, this is important because fragmentation of habitats is one of the most important factors in the decline of biodiversity in the landscapes altered greatly by human activity. Such activity means large areas of the landscape are transformed unfavourably into areas that are unsuitable for the completion of lifecycles and for movement around the matrix. New habitats occurring in areas with a high proportion of matrices, such as in agricultural and urban landscapes, can increase communication between populations by reducing the negative effects of habitat fragmentation. On the other hand, new habitats can be a barrier to the effect of landscape fragmentation. The isolating effect may be the result of the way in which a given group of organisms uses new habitats, for example, as a food source. It can also change over time, depending on access to resources in the new habitat.

The research examined whether new habitats created by the dominating open areas by invasive goldenrod species could create barriers to the movement of pollinating insects in the agricultural landscape. For this purpose, we examined the distribution of pollinating insects across the border between two habitats: meadows, and habitats dominated by invasive goldenrod. The control was land bordering meadows and cultivated fields. The research also took into account the possibility of changes in the distribution of pollinators across the borders, depending on the availability of food for pollinating insects (the goldenrod flowering period). It turned out that, in the pre-flowering period, the abundance and the diversity of pollinating insects increased from the goldenrod area, across the border, to the middle of the meadow. During the flowering period, the number of species and bees was evenly distributed between the meadow and goldenrod habitat. In the case of butterflies, the goldenrod flowering period did not affect the distribution of species and individuals between the meadow and the goldenrod habitat. The number of hoverfly species and individuals increased from the centre of the meadow, across the border to the middle of the goldenrod habitat during the flowering period. In the control border, the goldenrod flowering period had no effect on changes in the distribution of pollinating insects. It is worth mentioning that the isolating effect produced by goldenrod, especially when not in bloom, is as strong as the isolating effect caused by arable land, with the diversity and abundance of pollinating insects falling to 50 metres from the borders of goldenrod habitats and fields.

The results indicate the potential of isolation, modifying the distribution of pollinating insects, and the influence of habitats dominated by invasive goldenrod species. This isolating effect is dependent on the distribution of food resources available for pollinating insects. It is probably the result of behavioural avoidance of goldenrod patches, especially in the period before flowering, rather than any inability on the part of the pollinators. Thus, the availability of resources may explain whether new habitats have the potential to increase landscape fragmentation (in the case of goldenrod habitats), or to increase communication between populations (railway embankments and flood embankments) in landscapes greatly altered by humans.

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In summary, this research on the biodiversity of new habitats such as railway embankments and flood embankments was in principle limited to censuses of species, and individual studies of ecological processes such as the movement of organisms concerned only plants. The presented works indicate not only that such man-made structures are valuable new habitats for pollinating insects and plants, but also show, with GIS analysis, which features of these structures and their surrounding environment have a positive influence on biodiversity. It is very important to note that railway and flood embankments support the movement of pollinating insects and plants in landscapes greatly transformed by humans.

There are very few studies indicating the mechanism responsible for the distribution of relatively mobile species, such as insects, in new habitats created by invasive plants. It turned out that the availability of food in time and space is the main factor affecting the distribution of pollinating insects in such habitats. In addition, in the study of invasive species, the most common linear relationship between the density of invasive species and their impact on native species is assumed. However, considering the complex interactions between species, we should rather expect non-linear relationships. The research indicates that non-linear relationships describe changes in the biodiversity of pollinating insects with the formation of a new habitats dominated by invasive plants. This has great practical implications, as it allows the restitution of habitats along with a high level of biodiversity, even when the process of invasion is greatly advanced.

Changes wrought by civilisation often entail unforeseen changes in the landscape, some of which can be used to preserve biodiversity and important ecological processes. The presented works indicate that, in the case of some new habitats (railway embankments and flood embankments), such preservation is possible, while in others (goldenrod stands) it is not.

Thus, properly managed infrastructure can be a substitute for valuable natural and semi-natural habitats which are missing from the landscapes of highly developed countries. The habitats created by invasive species are characterised by certain features (isolation and lack of food) that make it impossible to consider them as substitutes for natural habitats. It seems that consideration of the potential of new habitats in maintaining ecological diversity and processes should be considered separately for each of these habitats.

5. Other scientific activities.

5A. Pre-doctorate period.

Before my doctorate, my scientific interests focused on insect biology, which resulted in research into the behavioural ecology of social insects. These studies concerned the division of labour among ants of the genus *Myrmica* (work [P18]) and honey bees [P20]. The taking up of various tasks by workers among social insects, from caring for offspring to collecting food, is called the non-productive division of labour. Tasks undertaken by female workers vary in terms of risk level, from safe tasks inside the nest to more dangerous ones outside. As a rule, safe tasks are performed by young workers, while older ones carry out risky work related to getting food. Despite the universality of the described pattern of behaviours, the ultimate causes of this type of division of labour in social insects were not known. The conducted research indicated that the life expectancy of the workers, rather than their absolute age, was the deciding factor for risky activity. The shorter the life expectancy, the greater the willingness of the workers to take on dangerous work. In this way, the average life expectancy of workers in the colony increases, which confers an evolutionary advantage.

After passing my doctoral exam at the Jagiellonian University, I took part in the work of the "ALARM" project funded by the European Union. This project concerned, among other things, the biology and ecology of pollinating organisms (in our climatic zone these are mainly insects). Plant pollination by animals plays a key role in maintaining high biodiversity, and is one of the most important ecosystem services. Therefore, pollinating organisms can be considered as a key group for the functioning of natural habitats and those greatly transformed by humans. Research on pollinating insects is important because populations of these insects are now seriously threatened by the decline in diversity and abundance. The research made it possible to identify wet meadows as a habitat at the centre of bee diversity in the agricultural landscape [P19]. It had been thought that bee biodiversity centres were mainly xerothermic. During the project, it was found that invasive plants that dominate in the habitat may pose a threat to the diversity of native pollinators [P21]. Invasive species of North American goldenrod transform the habitat, mainly through the accumulation of dead organic matter and a reduction of the diversity of native plants, significantly reducing the diversity of pollinator populations. Research on pollinators carried out as part of the ALARM project also provided the inspiration to undertake broader work on the ecology of pollinators and the pollination process in my post-doctoral period.

5B. Post-doctorate period.

After defending my doctoral thesis, I was employed at the Institute of Systematics and Evolution of Animals at the Polish Academy of Sciences in Kraków. During this period, I continued research on the non-reproduction division of labour in ants under a grant from the Ministry of Science and Higher Education. It had been thought that workers with shorter life expectancy would take on risky work outside the nest. Research showed that life expectancy has a subtler influence on which individuals undertake work of varying degrees of risk [P30]. Tasks outside the nest, and of differing risk levels, are undertaken by workers with different life expectancy. This indicates the key impact of life expectancy on the deployment of workers in the colony, and on most of the tasks they undertake. We suggest that the creation of a community by individuals with different life expectancy could be of great importance for the evolution of eusocial systems.

I have also begun intensive research on the effects of high concentrations of heavy metals in the environment on populations of pollinating insects and on the effectiveness of the pollination process. Part of the research was carried out at Poznań University of Life Sciences University (grant received from the National Science Centre). Heavy metals cause changes in the functioning of many basic ecological processes. The most frequently studied processes, modified by the presence of metals in the environment, are primary production and decomposition. Until now, the diversity of pollinating insects and the process of pollination in areas exposed to high concentrations of heavy metals has not received much attention. Yet such areas are, at least in highly developed countries, relatively high in number. The research showed that the number of bee species and individuals (bees being the main group of species pollinating the temperate zone), drops sharply as heavy metal contamination of soil and pollen increases [P16, P25]. Also, the parameters of the adjustment of female mason bees (one of the most important bee species used in agriculture), such as the number of offspring and their survival, decreased with the concentration of heavy metals in the environment [P34]. We also noticed that the sex ratio in contaminated areas is tilted in favour of females. This lowering of the parameters of female adjustment is reflected in a clear decrease in the population growth rate in areas contaminated with heavy metals. Our research indicates the direct, toxic impact of heavy metals in the environment on pollinating insects, over and above indirect effects (such as through the negative influence of environmental contamination on plants). On the other hand, we did not find any evidence for the existence of greater asymmetry of the wings of garden mason bees from contaminated areas [P41]. Body asymmetry is postulated as one of the negative symptoms of contamination of the environment with heavy metals. Our work indicates the need to take into account the decline in the diversity of pollinating insects and the effectiveness of pollination in areas exposed to heavy metal contamination, which may be important for the phytoremediation of degraded areas. Subsequent work on the presence of heavy metals in the environment on the efficiency of the pollination process is underway.

I also continued a broader study of the relationship between insect biology and the changes in the agricultural landscape, especially the invasions of alien plant species accompanying this [P17]. In subsequent studies, we showed that invasive plants have a strong negative impact on the whole ecosystem, from ants [P32, P39, P43 and P44] up to birds [P27 and P42]. In the case of ants, it was shown that the invasion of foreign goldenrod and impatiens has a negative impact on the colonies and their size. The presence of invasive plants also modifies colony investments. In areas with invasive plants, ant colonies invest less in growth and more in the production of fertile offspring. Our research indicates that the negative impact of invasive plants results mainly from the reduced availability of food and the associated pattern of food acquisition, for example the need to make longer trips to obtain resources. Invasive plants also affect the presence of ants by changing the microclimatic conditions in the habitat. The mechanism of the spread of walnut as an invasive species is extremely interesting. The colonisation of post-agricultural areas was possible thanks to the native crows, which gathered walnut seeds from gardens and stored them in arable lands as a long-term food supply. Some of these nuts are not recovered, so they can germinate but the seedlings are destroyed by ploughing, which inhibits the spread of this plant. On the other hand, if work in the field is discontinued, the seedlings can grow freely. Such a large-scale cessation of farming took place after the political and economic transformation in Poland in 1989. Our research showed a special relationship between the occurrence of invasion and political changes. In addition, I participated in studies showing how sociological changes, especially the development of the Internet, influence the emergence of new dispersion patterns of invasive plant species [P35].

Landscape changes are not just about the appearance of alien species, but are associated with a number of phenomena, such as the intensification of agriculture and urbanisation. A number of our studies concerned the application of new methods of agricultural production, such as sowing from polyethylene materials and their impact on the functioning of agricultural ecosystems. The use of foil shields creates a large-scale disturbance in the habitats of field birds in the breeding period crucial for them [P33]. This results in a significant reduction in the number of species, an effect which persists even after the foil is removed from the crop. The intensification of agricultural activity results, among other things, in reducing the number of habitats available for pollinating insects. Or results indicate that, in order to protect pollinating insects in the agricultural landscape, the preservation of habitat patches of appropriate size is of greatest importance [P22 and P26]. Additionally, such patches should be at a distance apart sufficient to ensure communication between populations. Economic changes in the agricultural landscape may entail a growing share of new buildings related to agricultural production, leading to a range of new threats to biodiversity. Large-scale greenhouses are examples of such buildings. Colonies of bumblebees from different parts of the world are commonly imported to pollinate greenhouse crops. Bee transport on such a large scale may involve new threats [P15, P23 and P28]. Our research made it possible to determine the introgression taking place, with the males emerging from the greenhouse to enrich the gene pool of the local population. Because the greenhouse bees come from warmer climates, there is a fear that the local population will experience a winter period. Greenhouse colonies of bumblebees can also be a source of parasites such as protozoa or mites.

Another topic that I have been involved in is road ecology. As part of the conducted research, it has been shown that the mortality of pollinators on roads is a non-random process in space, and that there are places where most such cases are concentrated [P37 and P47]. These "black spots" spatially occupy only a few per cent of overall road length, but account for almost 50% of all dead insects. It was also shown that insect mortality on roads is primarily related to low-flying species of small body size [P31]. Insect mortality on roads can be reduced by maintaining appropriate vegetation and mowing regime.

While studying the biology of pollinating insects, I was also interested in the subject of post-industrial areas. Contrary to appearances, such heavily transformed environments such as gravel pits, settlements and mines have features that allow them to play an important role in maintaining the richness of local species [P29]. This is important from the point of view of nature conservation because not all natural ecosystems can be protected. This suggests using a different approach that seeks to exploit the possible means of protecting species richness created by industrial development. It also provides the tools required to eliminate environmental and economic conflicts.

I have also been involved in studies on the specificity of the parasite-host system of the scarce large blue butterfly and the European fire ant [P24]. Research has shown that the scarce large blue is capable of using different species of fire ants as hosts for larvae development. Hence the conclusion that this butterfly is not evolutionarily adapted to select only one species of ant.

5C. Plans for the future.

For the foreseeable future, I plan to continue research on landscape ecology in the light of threats to pollinating insect populations. I am currently conducting extensive research on the impact of increased heavy metal concentration on populations of pollinating insects in the context of climate change. In particular, I will investigate whether extreme, increasingly common atmospheric phenomena, such as heat waves and cold snaps, in combination with heavy metal pollution of the environment, influence the efficiency of the pollination process. I also plan to develop my analytical skills, especially through learning advanced programming techniques in R and Python environments, and continuous improvement of satellite image analysis tools in GIS. I plan to use these methods in the consideration and analysis of ecological processes in landscapes.

Dawid Moroń

Kraków, 6.12.2018 Dawid Moroń