ATTACHMENT 3

Summary of professional accomplishments

Krzysztof Miler, PhD

Institute of Systematics and Evolution of Animals

Polish Academy of Sciences

Kraków 2022

1. Name.

   Krzysztof Miler

2. Diplomas, degrees conferred in specific areas of science, including the name of the institution which conferred the degree, year of degree conferment and title of the dissertation.

   - **2018** – PhD in Biology, Jagiellonian University (Institute of Environmental Sciences). Title of the PhD dissertation: “Predator-prey system of antlions and ants: hunting strategies and rescue behaviours”.
     Advisor: prof. dr hab. Michał Woyciechowski.
     PhD degree conferment date: 23.10.2018.

   - **2015** – MA in Psychology, Jagiellonian University (Institute of Psychology). Title of the MA thesis: „Odwzajemnienie: ujęcie psychologiczne i przyrodnicze” (in Polish).
     Advisor: dr hab. Dorota Czyżowska.
     MA title conferment date: 13.10.2015.

   - **2015** – MSc in Biology, Jagiellonian University (Institute of Environmental Sciences). Title of the MSc thesis: „Międzygatunkowe zależności w koloniach samotnych pszczół” (in Polish).
     Advisor: prof. dr hab. Michał Woyciechowski.
     MSc title conferment date: 24.06.2015.

3. Information on employment in research institutes or faculties/departments.

   - 2019-09-16 – currently; **adjunct**, Institute of Systematics and Evolution of Animals of the Polish Academy of Sciences.
   - 2016-06-17 – 2018-12-31; **research assistant**, Jagiellonian University (Institute of Environmental Sciences).

- 2015-06-01 – 2017-11-30; **technician**, Jagiellonian University (Institute of Environmental Sciences).

4. Description of the achievements, set put in art. 2019 para 1 point 2 of the Act.

A. Achievement title

Thermal ecology of trap building insects.

B. Publications included in the achievement, with the *impact factor* (IF) of the journal according to JCR and the number of ministerial points, according to lists for the publication year or the newest available listing

(I) **Miler, K.**, Stec, D., Czarnoleski, M. (2020). Heat wave effects on the behavior and life history traits of sedentary antlions.
Behavioral Ecology 31:1326-1333. IF_{2020} = 2.671. $MNiSW_{2020}$ = 140.

(II) **Miler, K.**, Czarnoleski, M. (2021). Past thermal conditions affect hunting behaviour in larval antlions.
Royal Society Open Science 8:210163. IF_{2020} = 2.963. $MEiN_{2021}$ = 100.

(III) **Miler, K.**, Czarnoleski, M. (2022). Heat stress during development makes antlion larvae more responsive to vibrational cues.
Current Zoology 68:345-350. IF_{2020} = 2.624. $MEiN_{2021}$ = 100.

(IV) **Miler, K.**, Scharf, I. (2022). Operant conditioning in antlion larvae and its impairment following exposure to elevated temperatures.
Animal Cognition 25:509-518. IF_{2020} = 3.084. $MEiN_{2021}$ = 140.

C. Description of the aim and obtained results

BACKGROUND

Antlions (neuropteran insects belonging to the family Myrmeleontidae) occur in various, although usually dry and sandy environments. In a significant number of antlion species, the life cycle includes predatory larvae that build inverted cone-shaped traps in the sand (Figure 1). The larvae use these traps to hunt small invertebrates, particularly ants (hence their name, antlions). In the temperate zone, the larval period of development may last two or even three years in extreme cases, and so dominates in the entire life cycle. Adult insects are short-lived and have poor flying abilities. In trap-building species, larvae after their trap establishment can be considered relatively sedentary as they avoid relocation that imposes marked costs (e.g. energetic). For that reason, trap-building antlion larvae are an excellent model for the study of biotic and abiotic environmental influences on, for example, physiology or behaviour. These kinds of influences raise scientific interest among entomologists for a long time, especially in the context of microhabitat preferences of larvae (for a review see Scharf & Ovadia 2001) and behavioural plasticity in response to environmental factors (for a review see Scharf, Lubin & Ovadia 2011).

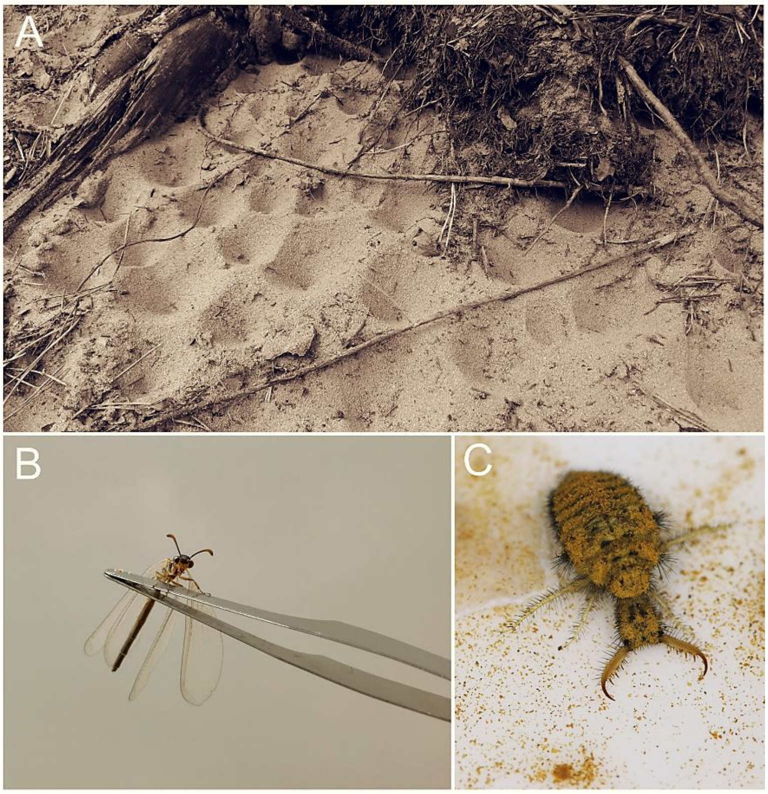

Figure 1. Aggregation of traps built by *Euroleon nostras* (Geoffroy 1785) antlion larvae around the Błędowska desert (panel A). Adult *Myrmeleon hyalinus* (Olivier 1811) individual – representative of Israeli antlion fauna – raised in the laboratory (panel B). The third and last instar larva of *Myrmeleon bore* (Tjeder 1941), collected in the Błędowska desert. Photographs: K. Miler.

Low dispersal of antlions, both of the adults – stemming from poor flying abilities during their short lives – and of larvae – stemming from their relative sedentarism and relocation to short distances at best – implies that they are subject to potentially strong selection acting through environmental factors. Temperature is one of such factors of fundamental importance in the lives of ectothermic organisms, including insects such as antlions. Larvae, because they require dry sand for functioning, very often inhabit highly xerothermic environments. Their abilities for living in conditions of thermal extremes seem to be marked, but how these conditions affect larval functioning remains largely unknown. Four publications that constitute the achievement submitted herein to obtain the post-doctoral degree of doctor habilitated concern exactly these issues. Below I will shortly present and discuss each publication.

PUBLICATION I

July 2021 has been announced the hottest month on the record for our planet (NOAA 2021). This wicked score is part of a general, global trend associated with ongoing climatic changes (IPCC 2021). Although an increase in mean temperatures is a highly important parameter in the context of climate change, such phenomena as an increase in frequency and intensity of extreme weather events are an integral part of these ongoing changes. These events include, among others, floods, droughts, cyclones, and heatwaves. In Europe, heatwaves have been especially pronounced in recent years. For example, heatwaves lasting for a few days and with the temperature reaching 40°C in several places around Europe are largely responsible for the July 2021 record.

My research presented in p u b l i c a t i o n I concerns responses of antlion larvae to heatwaves. In the study, I simulated a heatwave in a climatic chamber, which took the form of ambient temperature increasing in the morning from 25 to 40°C and remaining on that level until evening, when it dropped from 40 to 25°C. I repeated such a daily cycle for 7 days, simulating a week-long heatwave. During that week, I measured larval survival, activity (i.e. readiness to hunt), and how their body mass changed in relation to that at the beginning (before simulation). Moreover, because I reared larvae in standard conditions for several more weeks afterward, I measured how the simulation affected their speed of progress into another instar stage as well as their final body mass – in which larvae would enter overwintering in natural conditions. All these parameters were measured in comparison to the control group of larvae that experienced no simulated heatwave. My hypotheses stated that (1) mortality of larvae would increase when exposed to heatwave, but (2) their activity and body mass would decrease. Furthermore, in the period after the simulated heatwave, (3) time needed to progress to the next instar stage in these larvae would increase and they would enter overwintering in poorer condition (i.e. lower final body mass). I performed the experiment using two species of antlions present in Polish fauna, *Myrmeleon bore* Tjeder 1941 and *Euroleon nostras* Geoffroy 1785 (Figure 1).

My study has shown that the heatwave increased the mortality of *E. nostras* larvae. Moreover, these larvae decreased their activity during the simulated heatwave. Their body mass changed as well, in the expected direction – significantly decreased in larvae exposed to the heatwave. After the heatwave ceased, *E. nostras* larvae also demonstrated increased developmental time of progress to the next instar stage. A similar effect was not observed in the case of *M. bore* larvae. Importantly, long-term consequences of the simulated heatwave in the context of final body mass were completely absent in both species. Thus, the results have confirmed my hypotheses only partially. First and foremost, expected effects of the heatwave were visible in one of the species only, which suggested local adaptations resulting from differences in ecological niches of the species. Indeed, *M. bore* larvae inhabit different environments – open and exposed to direct sunlight – than *E. nostras* larvae which favour shaded microhabitats. This corresponds to my results which suggest that larvae from shaded environments are less resistant to the effects of extreme temperatures. No less importantly, however, my results suggest that although high temperatures might contribute to temporal instability in life-history traits of some species of larvae, the long-term effects of these temperatures are minor. This confirms the supposed well-marked abilities of antlion larvae for living in conditions of thermal extremes.

The significance of the research presented in p u b l i c a t i o n I focuses on the comparison of behavioural reactions and changes in life-history traits to those reported for other ectothermic organisms, enabling evaluation of how well different taxa are adapted for the ongoing climatic changes (Buchholz *et al*. 2019). Nevertheless, the significance of the research is not limited to demonstrating how antlion larvae react to extreme weather events in the form of a heatwave. My study suggests the importance of extended phenotype in predicting the consequences of climatic changes on organisms. Extended phenotype refers to traits that go beyond the body surface and, although common, are rarely accounted for in models of the influence of climate on animals (Woods *et al*. 2021). Such structures as burrows or nests or, in the case of antlion larvae – their traps established in the sand – may act as a buffer or amplifier of the effect of environmental factors. Sand is a poor conductor of heat and it seems likely that it buffers the influence of high temperature, similarly to larval decisions concerning activity ceasing in conditions of thermal extremes. My research highlights the importance of extended phenotype in the form of traps for local thermal niche construction of antlion larvae and the significance of these niches in the context of plasticity and fitness.

PUBLICATION II

In research presented in p u b l i c a t i o n I I , my goal was to check how exposure of antlion larvae to relatively high temperatures affects their extended phenotype in terms of parameters relevant for fitness. I assumed that these parameters include the size of traps and the distance between traps established by pairs of larvae. I designed an appropriate experiment and used *E. nostras* larvae. Considering their thermal sensitivity (p u b l i c a t i o n I) I devoted special attention to arranging thermal conditions in such a way to provide a stressor, but lead to no increase in mortality. To this aim, I performed tests of the preferred and critical temperature of larvae, and based on the results I chose conditions of increased and more optimal temperature (31 and 25°C, respectively). Next, I reared larvae in these conditions for an arbitrarily chosen time (i.e. a month), fed them, and followed their development until I moved them to common, standard conditions and allowed them some time for acclimation. My hypothesis stated that experience of increased temperature in the past would adaptively change extended phenotype. In other words, I expected bigger traps and higher distances between traps in larvae after such an experience when compared to those raised in more optimal temperatures. Existing data dictated these expectations as bigger traps allow to catch bigger prey, while higher distances between traps impose lower maintenance costs and decreased intraspecific competition (for a review see Scharf, Lubin & Ovadia 2011). These changes would be adaptive because potentially, they would help larvae catch up on the energetic costs of living in suboptimal conditions. My results, however, indicated the opposite trend – larvae that originated from rearing conditions characterized by increased temperature built slightly smaller traps and established them a bit closer to each other than those raised in more optimal thermal conditions.

Observed changes unlikely stemmed from the exhaustion of larvae raised in conditions of increased temperature. During development, the larvae lost a small percentage of their body mass and I detected no mortality at all. I hypothesize that observed reactions of larvae might, despite appearances, lead to compensation of past thermal experiences, just in a less intuitive way than I expected initially. Increasing density may, for instance, lead to the so-called ricochet effect observed in another group of trap-building predatory animals – spiders (e.g. Uetz 1989). The effect consists of increased hunting efficiency in a close aggregation of traps because prey fatigues more quickly and when it escapes from one may easily fall into another. *E. nostras* antlion larvae often occur in more or less compacted aggregations (Figure 1). Increased tendency to aggregate, expressed in lower distances between trap-building larvae, may present an attempt in compensating for the experienced costs via the ricochet effect or other, unknown mechanisms. A decrease in the size of traps in the group of larvae raised in increased temperature might be nothing more than a natural consequence of lower distances between traps.

The study presented in p u b l i c a t i o n I I is valuable because it points out various potential mechanisms that compensate for past experiences of antlion larvae and demonstrate that these experiences may mediate larval decisions regarding the construction of extended phenotype. Similar mediators have been described in the literature. For example, some life-history traits of larvae depend on food availability experienced in the past – even when it is currently similar (e.g. Rotkopf *et al*. 2013). Demonstration that thermal experience may act as a mediator for the size of traps and distance between traps of antlion larvae expands our understanding of their traits that are crucial for fitness. Furthermore, considering the long development of larvae, my work highlights the need to study what and how is changed through their experience. This applies not only to thermal experience but any other that results from the action of biotic or abiotic environmental factors. Nevertheless, it is worth noting here that the results of the study do not indicate any dramatic effects of living in increased temperature. This confirms once again that thermal extremes are well tolerated by antlion larvae.

PUBLICATION III

The research report in p u b l i c a t i o n I I I is a continuation of studies on the effect of thermal experience on antlion larvae. In this work, I utilized *M. bore* larvae, more resistant to high temperatures than *E. nostras* (publication I). Similar to the previous experiment (publication II) I performed tests of the preferred and critical temperature of larvae, and based on the results I chose thermal conditions in which I then reared larvae, i.e. conditions of increased temperature (36°C) and more optimal (30°C). These temperatures had to differ from those used for *E. nostras* as a direct consequence of the tests and earlier results (publication I). The experiment aimed to apply a relatively high, stressful temperature lasting until the transition into another instar stage (as opposed to an arbitrarily chosen period) and to observe the consequences of this thermal experience for vibration sensitivity. This was compared to larvae that changed instars in more optimal thermal conditions. Vibration sensitivity is an important parameter of hunting efficiency in antlion larvae. Their bodies are covered in numerous mechanoreceptors that enable them to detect vibrations caused, for example, by a potential victim walking on the sand surface (for a review see Devetak 2014). Perception of vibrations and their identification allows larvae to increase hunting efficiency. I wanted to evoke the costs of coping with thermal stress by applying significantly increased temperature at the time of a crucial developmental event (i.e. moulting) that could potentially lead to hindered vibration detection capabilities and further fitness costs.

As such, I raised larvae in the abovementioned conditions, fed them, and followed their development. Afterward, I moved them to common, standard conditions and allowed them some time for acclimation. My primary hypothesis stated that larvae reared earlier in increased temperature would be worse at detecting vibrations than larvae that originated from more optimal temperatures. I detected the opposite effect. Larvae developed in increased temperature, when compared to those from more optimal temperatures, reacted to vibrations from further away. A group of larvae that experienced increased temperature demonstrated increased mortality as well. It is not out of the question that the results for vibration sensitivity were a consequence of individuals with lower abilities to detect vibrations not surviving the experiment. However, mortality was likely unrelated to vibration sensitivity and it was the past thermal experience that changed it in larvae that survived. This scenario suggests a potential way of compensation for past experiences in antlion larvae.

Similar to research presented in publication II the one described in publication III points out various potential compensatory mechanisms of past experiences in antlion larvae. It is worth underlining that conditions of development of sensitivity to vibrations and its dependence on environmental factors are very poorly researched. Thus, this work can contribute to increasing interest in biotremology, for example in antlion larvae. Both behavioural and ecological aspects of larval biotremology await further study, similarly to how the methods and tools used in this context await development. Of note, this subject is currently receiving some increased interest from researchers (Strauß *et al*. 2021). My study fits into a research direction that tackles questions of sources of variation in vibration sensitivity and selection pressure on strategies that utilize vibration for leading a predatory lifestyle. Results of my research clearly show that there is a limit to suboptimal thermal conditions that antlion larvae can tolerate. The limit is connected to the acting period and/or developmental stage at which thermal extremes are experienced by larvae.

PUBLICATION IV

Detection of vibrations enables antlion larvae to react to what is happening in their surroundings (p u b l i c a t i o n I I I). In the past, this ability was used by other authors and me for the study of learning in larvae. It has been shown, for example, that hunting efficiency increases in larvae exposed to repeatable events in which vibrations announce incoming prey, in comparison to situations in which prey drops into traps unannounced (Hollis *et al*. 2011). To use another example, my co-authors and I have demonstrated that variation in speed of learning (i.e. associating vibrations with incoming prey) depends on the degree of behavioural asymmetry (Miler *et al*. 2017). Nevertheless, as I already mentioned above, methods and tools connected to biotremology of antlion larvae need further development – because, among other reasons, they are characterized by poor standardization. In research presented in p u b l i c a t i o n I V I dealt with the theme of learning in antlion larvae. In the first step, I developed a novel methodology enabling the study of larval learning and completely omitting vibratory stimulation. The new methodology was inspired by classical studies of T-maze learning in beetle larvae belonging to the genus *Tenebrio* Linnaeus 1758 (Alloway & Routtenberg 1967). In the first experiment presented in p u b l i c a t i o n I V I showed that if one arm of such a maze leads to a place with dry sand available for trap building, then antlion larvae placed in the maze learn to turn in the direction of that arm. This method is highly standardizable and enables one to conduct many interesting experiments.

In the second experiment presented in publication IV I aimed to compare the speed of learning in a maze and retention (i.e. memory) of how to behave in a maze in larvae raised earlier in more or less thermally optimal conditions. I performed the experiment during my post-doc fellowship in Israel and used species of larvae characteristic of Israeli fauna, *Myrmeleon hyalinus* Olivier 1811 (Figure 1). I chose rearing temperatures – more and less optimal – based on earlier research conducted on the same species and set them to 25 and 29°C, respectively. Similar to my earlier work (publication III), I applied these thermal conditions and used them to raise larvae while I fed them regularly and followed their development until the transition to another instar stage. Then I moved them to common, standard conditions. Next, I conducted larval training in the T-maze and measured their speed of learning. After the training was done, I applied two weeks of break, after which I checked how larvae react in the maze and whether their reaction is correct (i.e. they turn in the appropriate direction) or incorrect (they turn in the wrong direction). I hypothesized that larvae reared in less optimal (meaning higher) temperatures would be slower learners and would remember what they have learned less well than larvae that originated from more optimal rearing conditions (meaning lower temperature). This expectation was dictated by potentially increased costs of living in an increased temperature and worse allocation of limited resources to the development of structures responsible for cognitive abilities such as learning or memory.

The results partially confirmed my hypothesis. I detected no change in speed of learning in larvae raised in less optimal conditions when compared to those originating from more optimal ones, yet the former were characterized by worse retention. After two weeks after the training, significantly more larvae turned in the correct direction when raised at 25°C than 29°C.

The study presented in publication IV is valuable as it illustrates operant conditioning in antlion larvae for the first time (Miler & Scharf 2022). Operant conditioning is a learning process in which the consequences of actions determine similar actions in the future. In the context of larvae and their training, turning to a certain side in a maze can be rewarded with ending up in an environment that allows for building a trap and hunting. As I have shown, larvae learn that this relationship exists and it determines their later decisions when they face a familiar problem in the maze. Other than that, this work indicates the effect of thermal conditions during development on learning retention in larvae. This result is valuable as results of similar experiments on different taxa are mixed. Discovering potential factors that contribute to these mixed results can only be possible with more research utilizing a similar methodology. My study suggests handicapped cognitive ability in individuals exposed to increased temperature.

FINAL REMARKS

Presented publications, which utilized antlion larvae as a model, significantly contribute to our understanding of thermal ecology. Publication I describes how heatwave strike affects selected life-history traits in two species of larvae that differ in their microhabitat preference, publication II indicates that the distance between traps of different larvae and the size of their traps may at least in part be a result of past thermal experiences, publication III demonstrates how larval population changes one of the key parameters in successful hunting, i.e. vibration sensitivity, after it encounters too high temperature, and publication IV presents the first evidence for operant conditioning in larvae and delivers novel information on the effect of thermal experience on memory. Each work involves original experimental protocols utilized for the study of larvae (i.e. heatwave simulation, methods for determination of preferred and critical temperatures, conditioning procedures). These methods can be successfully used in further research. The studies demonstrate several effects that might be more or less pronounced also in other animal species, including also other trap-building animals such as, for example, web-building spiders.

All four publications are a result of my research project SONATINA 3 funded by the National Science Centre, Poland. Since I was a principal investigator and sole executor of the grant, my role in developing these works was crucial. Nevertheless, I would like to acknowledge my co-authors' contribution, without whom preparing this cycle of publications would be much harder. I greatly appreciate their help.

LITERATURE CITED

Alloway, T.M., Routtenberg, A. 1967. "Reminiscence" in the cold flour beetle (*Tenebrio molitor*). *Science* 24:1066-1067.

Buchholz, R., Banusiewicz, J.D., Burgess, S., Crocker-Buta, S., Eveland, L., Fuller, L. 2019. Behavioural research priorities for the study of animal response to climate change. *Animal Behaviour* 150:127-137.

Devetak, D. 2014. Sand-borne vibrations in prey detection and orientation of antlions. W: Cockroft, R., Gogala, M., Hill, P., Wessel, A. *Studying vibrational communication*. Heidelberg, Springer. S. 319-330.

Hollis, K.L., Cogswell, H., Guillette, L.M., Nowbahari, E. 2011. Specialized learning in antlions (Neuroptera: Myrmeleontidae), pit-building predators, shortens vulnerable larval stage. *PLOS ONE* 6:e17958.

Intergovernmental Panel on Climate Change. 2021. *Assessment Report 6, Climate Change 2021: The Physical Science Basis*. Online: www.ipcc.ch/report/ar6/wg1.

Miler, K., Kuszewska, K., Woyciechowski, M. 2017. Larval antlions with more pronounced behavioural asymmetry show enhanced cognitive skills. *Biology Letters* 13:20160789.

Miler, K., Scharf, I. 2022. Convergent evolution of antlions and wormlions: similarities and differences in the behavioral ecology of unrelated trap-building predators. *Behavioral Ecology and Sociobiology* 76:12.

National Oceanic and Atmospheric Administration. 2021. *It's official: July was Earth's hottest month on record*. Online: www.noaa.gov/news/its-official-july-2021-was-earths-hottest-month-on-record.

Rotkopf, R., Alcalay, Y., Ber-Hanin, E., Barkae, E.D., Ovadia, O. 2013. Slow growth improves compensation ability: examining growth rate and starvation endurance in pit-building antlions from semi-arid and hyper-arid regions. *Evolutionary Ecology* 27:1129-1144.

Scharf, I., Ovadia, O. 2006. Factors influencing site abandonment and site selection in a sit and wait predator: A review of pit-building antlion larvae. *Journal of Insect Behavior* 19:197-218.

Scharf, I., Lubin, Y., Ovadia, O. 2011. Foraging decisions and behavioural flexibility in trap-building predators: a review. *Biological Reviews* 86:626-639.

Strauß, J., Stritih-Peljhan, N., Nieri, R., Virant-Doberlet, M., Mazzoni, V. 2021. Communication by substrate-borne mechanical waves in insects: from basic to applied biotremology. *Advances in Insect Physiology* 61:189

Uetz, G.W. 1989. The 'ricochet effect' and prey capture in colonial spiders. *Oecologia* 81:154-159.

Woods, H.A., Pincebourde, S., Dillon, M.E., Terblanche, J.S. 2021. Extended phenotypes: buffers or amplifiers of climate change? *Trends in Ecology and Evolution* 36:889-898.

D. Individual contribution of the applicant in each publication

My contribution to each publication constituting the achievement was similar and leading. The contribution is confirmed in a separate declaration (attachment 5).

5. Information on any other scientific or research activity.

A. INTRODUCTION

I decided to apply for the conferment of the post-doctoral degree of doctor habilitated by describing a cycle of scientific articles related to the theme of thermal ecology of trap-building insects as, in my opinion, this subject reflects my independence well. However, my research conducted thus far is by no means restricted to this subject. Below I will shortly describe my broader scientific activity, dividing it into periods before and after I received the doctoral degree. In this description, I will repeatedly relate to scientific articles provided in full detail in the list of my scientific achievements (attachment 4).

B. PERIOD BEFORE THE DOCTORAL DEGREE

My earliest scientific experiences concern involvement in research supervised by advisors of my BSc and MSc theses in Biology. This resulted in co-authored publications (articles 1 and 11). These studies investigated sexual conflict in bulb mites and nesting preferences in solitary Aculeata, respectively. My early motivation for scientific work is highlighted by the fact that I published a research report from a study conducted during a field course in which I took part as a student. It was one of my first publications and it concerned palm-ant mutualism (article 4).

During my studies leading to the doctoral degree, I focused on predator-prey interaction of antlions and co-occurring ants. Articles 2, 5, 6, and 13 entered my doctoral dissertation. I published several additional original papers on the subject (articles 3, 8, 9, 10, and 12), that together sum up to my experience on the topic. These studies concerned the means by which antlion larvae increase their hunting efficiency on ants and the ways of escaping predation by antlions in ants. The former perspective involved the study of larval learning, including types of events related to vibratory signals that they can learn about and that might be of importance in their daily lives. This perspective also involved sources of variance in speed of learning in larvae as well as their hunting efficiency in relation to the size of the prey and thermal conditions. The second abovementioned perspective involved ant rescue behaviour in the form of help provided to another individual from the same colony that finds itself in a life-threatening situation. Rescue behaviour in ants can be observed, among other situations, when an ant gets captured by an antlion larva and struggles to get free at the bottom of its trap. Nestmates belonging to the same colony might attempt to release the captured individual. I studied the expression of rescue behaviour depending on individual life expectancy and communicatory skills of individuals as well as in different species that differed in their ecological niches. As a result of these studies, I specialized in methods of work with antlion larvae and ants, while my published works received a fair number of citations.

Before I received the doctoral degree, I took part in an OPUS 7 project funded by the National Science Centre, Poland (NCN), and published several co-authored works on the biology of rebel workers in the honeybee (articles 7, 15, and 16). Rebels are extremely interesting from an evolutionary point of view as they develop a more "selfish" phenotype compared to typical workers. By participating in this project I learned how to work with the honeybee and in the apiary. My involvement also motivated me to develop research ideas utilizing the honeybee as a model. This quickly led to a PRELUDIUM 10 NCN project that I wrote and received funding for, as a result of which I publish a paper on the effect of alcohol on worker behaviour. More precisely, the work concerned the tolerance effect to alcohol in workers of the honeybee (article 14). The realization of this project was for me a starting point for a new research direction.

In general terms, the period before I received the doctoral degree was a period in which my main scientific research interests crystallized into (1) ecological aspects of learning and hunting in sedentary predators, antlion larvae, (2) proximate and ultimate determinants of rescue behaviour in ants, and (3) potential use of workers of the honeybee in studies devoted to alcoholism. During this period I actively participated in international conferences and organized an international myrmecological conference in Kraków, together with my at-the-time PhD advisor.

C. PERIOD AFTER THE DOCTORAL DEGREE

Research that I conducted or in which I participated before receiving the doctoral degree and that utilized antlion larvae as a model contributed to my familiarity with these insects and enabled me to develop research ideas for future realization. As such, shortly after I received the doctoral degree, I applied for funding under the SONATINA 3 NCN project that later received funding, and the results of which constitute core scientific achievement submitted herein (articles 22, 25, 31, and 32). Receiving the funding enabled me to start my employment at the Institute of

Systematics and Evolution of Animals of the Polish Academy of Sciences (ISEA PAS). Shortly after receiving the doctoral degree, I completed a short research visit in Israel as well, under funding received under the START program. This initiated my collaboration with Tel Aviv University regarding the biology of trap-building insects. Later, under this topic, I applied for funding under the BEKKER 3 program of the Polish Agency for Academic Exchange (NAWA) that I received, and which enabled me to go back to Tel Aviv University. My year-long post-doctoral training in that institution ended earlier this year. As the SONATINA and BEKKER projects were somewhat related to one another, I managed to realize them concurrently and develop scientifically at a fairly good pace. Besides the works indicated for the achievement, I published several others under a broad theme of behavioural ecology of trap-building insects (articles 17, 28, 33, and 34). These works focused primarily on microhabitat preferences of larvae of such insects, and convergent evolution between antlion larvae and dipterans of the family Vermileonidae, which also possess larvae that build traps in the sand – at first sight undistinguishable from traps of antlions.

Generally, during the period after receiving the doctoral degree, I doubled my publication record. My published works constitute a continuation of each among research directions crystallized earlier. On the subject of rescue behaviour in ants I published experimental, review, and methodological papers (articles 21, 27, and 29). Regarding studies utilizing the honeybee, all of my published works involved experimental reports on variation in the effects of alcohol among worker subcastes, daily fluctuations of these effects, withdrawal effects after prolonged alcohol consumption, and tolerance to alcohol in workers (articles 23, 24, 26, and 30). Under both subjects, I began a close collaboration with doctoral students for whom I became an auxiliary advisor. They wrote applications for PRELUDIUM 16 NCN and PRELUDIUM 20 NCN programs under my supervision that received funding. Other than that, I actively and frequently participated in editorial work for two journals, *Journal of Zoology* and *Ecological Entomology*, and reviewed numerous articles for international journals.

D. FUTURE PLANS

In nearest future, I plan to continue research on all of the abovementioned subjects that appear in my past work. Under funding from the SONATA 17 NCN grant, I plan to study the non-linearity of the effects of various doses of alcohol on life parameters and behaviour of workers of the honeybee. Together with a doctoral student (funding under the PRELUDIUM 20 NCN program), I will also study the potential beneficial actions of low doses of alcohol on workers that suffer from a common disease of the honeybee, nosemosis. Besides that, I plan to continue developing studies on rescue behaviour in ants. The research that I now conduct together with a doctoral student (funding under the PRELUDIUM 16 NCN program) will focus on the mechanism of this behaviour (vibroacoustic signals) and its ultimate explanations on a between-species scale (ecological characteristics of various species of ants). I also plan to further develop a research theme related to convergence between trap-building insects. Collaboration that I established with Tel Aviv University will enable me to conduct further studies on flies belonging to the family Vermileonidae, and on their thermal and cognitive ecology in particular. This will open the way for comparisons and studies devoted to convergent evolution between these dipterans and neuropterans belonging to the family Myrmeleontidae.

6. Presentation of significant scientific activity carried out at more than one university, scientific institution, especially at foreign institutions.

I received the doctoral degree from the Jagiellonian University and afterward continued my scientific activity at the Institute of Systematics and Evolution of Animals of the Polish Academy of Sciences (ISEA PAS). During my employment at ISEA PAS, I realized three abroad scientific visits – a month-long research stay in Israel, under funding received from the Foundation for Polish Science in the START 2018 program, short research stay in Denmark, under the SYNTHESYS+ program of the European Commission, and year-long post-doctoral fellowship in Israel, under the BEKKER 3 NAWA program (attachment 4, points 2 and 7).

My first research stay in Israel enabled me to get familiar with the hosting team at Tel Aviv University that I visited and work on further plans for collaboration with the team. As a result, I returned there later for a year thanks to the funding received from NAWA. I consider my post-doctoral fellowship which ended on 31 March 2022 very successful. Its results include active participation in the scientific life of the hosting team and establishment of close collaboration with that team, the realization of research planned in the application for funding that resulted in publications (articles 28, 32, 33, and 34) as well as expansion of my experience in laboratory work with Vermileonidae flies (research model unavailable in Poland), which is something I plan to use in the future.

My research stay at the Natural History Museum of Denmark was realized under the SYNTHESYS+ project. A number of my studies utilizing antlion larvae were conducted on Borneo (articles 10 and 17), where Myrmeleontidae fauna is very poorly known. At the Museum that I visited for my short research stay, there is a large collection of Neuroptera, including tropical antlions. The visit aimed to conduct a preliminary comparative analysis of insects from Borneo and those deposited in the collection, in order to ease the identification and/or description of species that I utilized in Borneo in the future. Considering my research and export permits for conducting studies and exporting material, I plan to return to Borneo and continue studies devoted to unique, sympatric populations of trap-building neuropterans (Myrmeleontidae) and dipterans (Vermileonidae) that occur there. Hence, I consider my stay at the Natural History Museum of Denmark very valuable, despite it being short, as it expanded my knowledge of taxonomy and systematics of the oriental antlion fauna and, as such, was useful in the context of future research.

7. Presentation of teaching and organizational achievements as well as achievements in popularization of science.

Considering the fact that since I obtained my doctoral degree I am employed in a scientific post, my didactic experience is largely limited to the period before obtaining the degree. During my doctoral studies at the Jagiellonian University, I co-tutored courses for BSc and MSc students in Biology. These included two courses, “Biologia owadów społecznych” (“Social insect biology”, a course in Polish, academic years 2015/2016 and 2016/2017) and “Field course in tropical ecology” (a course in English, the academic year 2017/2018). During my doctoral studies, I co-hosted a myrmecological conference as well, the 7th Central European Workshop of Myrmecology (21-24.04.2017, 70 participants). I took part in popularizing events such as the Małopolska Noc Naukowców (Researcher’s Night, Małopolska) several times. In my publication record from that time I have two popular articles, listed below and published in 2015.

After I received my doctoral degree, my didactic achievements focus on supervising doctoral students. I'm an auxiliary advisor for two doctoral students at the Jagiellonian University (Mr. Filip Turza and Mrs. Monika Ostap-Chęć). I have a close and lively collaboration with both of them, which is illustrated by the fact that I supervise their projects. As already mentioned above, these are the PRELUDIUM 16 NCN and PRELUDIUM 20 NCN projects (attachment 4, point 5).

As part of my popularizing activity after receiving the doctoral degree I published a popular article about the use of honeybee workers in studies devoted to alcoholism. I also engaged in book translation by B.F. Skinner ("Science and human behavior") that was published in March 2022 by Wydawnictwo Naukowe PWN. The book is supplemented with a foreword in which I'm a co-author. I treat this translation as an example of my popularizing and didactic activity. Skinner's books are an inspiration for me since my MA studies in Psychology. I plan to translate more of his books into Polish.

Popular articles:

1. **Miler, K.** (2015). Wybrane zagadnienia dotyczące stałości i zmienności zachowania. *Kosmos* 64:229-238.
2. Banot, W., Oleś, W., **Miler, K.** (2015). Człowiek jako element środowiska: sprawa świadomości ekologicznej. *Wszechświat* 116:103-107.
3. Ostap-Chęć, M., **Miler, K.** (2022). Pszczoła miodna jako obiecujący gatunek modelowy w badaniach nad alkoholizmem. *Kosmos* 70:659-669.

Translations:

1. Skinner, B.F. (1953). Science and human behavior. Macmillan. (2022). Nauka i zachowanie człowieka. Wydawnictwo Naukowe PWN. Translation: **Miler, K.** Foreword: Bąbel, P., **Miler, K.**

8. Other information.

My research before receiving the doctoral degree was several times awarded with scholarships, including a year-long scholarship for outstanding achievements for doctoral students funded by the Ministry of Science and Higher Education (twice, in 2017 and 2018) as well as a year-long START scholarship funded by the Foundation for Polish Science (in 2018). After receiving the doctoral degree, my studies were honored by a three-year scholarship for outstanding young scientists funded by the Ministry of Science and Higher Education (in 2019).

Signed by / Podpisano przez:

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Date / Data: 2022-06-14 09:10