Appendix 3.

Summary of professional accomplishments

Dr Szymon Śniegula

Institute of Nature Conservation,
Polish Academy of Sciences
al. Adama Mickiewicza 33,
31-120 Kraków

Kraków, 2019

1. First name and surname

Szymon Śniegula

2. Academic experience

2015: Ph.D. in Biology, Institute of Nature Conservation, Polish Academy of Sciences
Thesis title: "Compensating developmental rate in dragonflies and damselflies (Odonata) as a response to photoperiod along a latitudinal gradient"
Supervisor: Prof. Frank Johansson

2009: M.Sc. in Biology, Umeå University, Sweden
Thesis title: "Correlation between photoperiod and development rate in the damselfly *Lestes sponsa* (HANSEMANN): A compensating mechanism across latitudes?"
Supervisor: Prof. Frank Johansson

2007: M.Sc. Eng., West Pomeranian University of Technology, Szczecin
Thesis title: "Dragonflies (Odonata) as a taxon of natural environment of the Borne Sulinowo Commune" [Ważki (Odonata) jako takson środowiska przyrodniczego gminy Borne Sulinowo)]
Supervisor: Prof. Alicja Dańczak

3. Work experience

VI 2015 – present: Researcher, Institute of Nature Conservation, Polish Academy of Sciences, Kraków, Poland

VIII 2015 – II 2016: Post-doc. Laboratory of Aquatic Ecology, Evolution and Conservation, Catholic University of Leuven, Belgium

VIII 2012: Research assistant, Institute of Nature Conservation, Polish Academy of Sciences, Kraków, Poland

2013 – 2014: Four monthly visits, Evolutionary Biology Centre, Uppsala University, Sweden

I 2011 – II 2011: Research visit, Department of Ecology and Environmental Science, Umeå University, Sweden

4. The academic achievement resulting from Article 16 Paragraph 2 of the Act of 14th March, 2003 about the academic degrees and academic title submitted for habilitation procedure.

a) Title of the academic achievement.
The scientific achievement consists of a series of five publications on „Some aspects of evolutionary ecology in a common spreadwing damselfly (*Lestes sponsa*) across environmental gradient". Pooled impact factor of these five papers is 15.859. Total number of points based on journal list ranked by Ministry of Science and Higher Education (MSHE) was 175. Declarations of co-authors contribution to the publications are to be found in Appendix 5.

b) Authors, titles of the publications, year, journal title.

1. **Śniegula S**, Gołąb MJ & Johansson F 2016 A large-scale latitudinal pattern of life-history traits in a strictly univoltine damselfly. Ecological Entomology 41: 459-472. (IF: 1,687, MSHE: 40)
My contribution to this paper is about 80%. I conceived the idea, designed the experiment, participated in data collection, analyzed data and wrote the manuscript.

2. **Śniegula S**, Gołąb MJ & Johansson F 2016 Time constraint effects on phenology and life history synchrony in a damselfly along a latitudinal gradient. Oikos 125: 414-423. (IF: 3,586, MSHE: 35)
My contribution to this paper is about 80%. I conceived the idea, designed the experiment, participated in data collection, analyzed data and wrote the manuscript.

3. **Śniegula S**, Gołąb MJ, Drobniak SM & Johansson F 2016 Seasonal time constraints reduce genetic variation in life-history traits along a latitudinal gradient. Journal of Animal Ecology 85: 187-198. (IF: 4,827, MSHE: 45)
My contribution to this paper is about 70%. I conceived the idea, designed the experiment, participated in data collection, analyzed part of the data and wrote the manuscript.

4. **Śniegula S**, Gołąb MJ, Drobniak SM, Johansson F 2018 The genetic variance but not the genetic co-variance of life history traits changes towards the north in a time-constrained insect. Journal of Evolutionary Biology 31: 853-865. (IF: 2,538, MSHE: 25)
My contribution to this paper is about 70%. I conceived the idea, designed the experiment, participated in data collection, analyzed part of the data and wrote the manuscript.

5. **Śniegula S**, Gołąb MJ & Johansson F 2017 Cannibalism and activity rate in larval damselflies increase along a latitudinal gradient as a consequence of time constraints. BMC Evolutionary Biology 17: 167. (IF: 3,221, MSHE: 30)
My contribution to this paper is about 75%. I conceived the idea, designed the experiment, participated in data collection, analyzed the data and wrote the manuscript.

c) A discussion of the scientific aims of the papers and the results achieved, together with a discussion of their possible use.

Species with wide geographic distributions experience different degrees of environmental constrains. For example, ambient temperatures and length of the growth seasons become progressively lower and shorted as one moves towards the Pole. However, organisms living along this environmental gradient evolved adaptive traits that allow them to live and reproduce even in extreme high latitude conditions. Yet, strong selection for particular traits should lead to low or even lack of genetic variation in these traits. Low genetic variation can limit evolutionary potential (Stearns 1992) and sets genetic constraint for further evolution (Eckert et al. 2008).

Organisms that live in temperate regions adjust their developmental rate using two key environmental cues, temperature and day length. Appropriate responses to these cues allow organisms to survive cold winters (e.g. by entering diapause when conditions deteriorate) or speeding up development during brief growth seasons. Nonetheless, accelerated development and growth, and hence increased metabolic rate, commonly lead to physiological costs in terms of developmental errors. Also other environmental factors such as biotic interactions can pose additional constraints for adaptation to seasonal and thermal conditions at high latitudes.

There have been numerous studies on adaptation to ecological gradients but, to my knowledge, none of them considered seasonal regulations of development and growth rates in response to key environmental cues, temperature and photoperiod, that change as the season progresses. In my opinion, results, conclusions and inferences from simplified experiments where constant thermo-photoperiods are used should not be extrapolated to what happens in nature. This is simply because in natural conditions organisms experience continuous changes in physical factors, not constant ones that are commonly used in laboratory set ups. The experimental methods are especially important when model organisms originate from natural populations and when individuals from multiple populations are considered.

During my PhD studies I mainly focused on the effects of a single environmental cue, photoperiod, on life history traits. During these studies I proved that photoperiod plays an important role in shaping growth and development rate that in turn affects phenological events. However, for deeper understanding of organisms responses to environmental changes it is important to take into account a number of other factors that affect living creatures. Following this, I expanded my experimental assumptions by (1) adding another key abiotic (temperature) and (2) abiotic (organisms interactions) factors, and (3) exposing individuals to constant common-garden temperature and photoperiod and simulated natural thermo-photoperiods. I also (4) expanded the sampling regions and tested individuals from central core- as well as marginal high- and low latitude populations. I my opinion, such multi-faceted approach gives a good chance for reliable estimation of phenomena occurring in nature, and strengthen predictions for the effects of global climate change.

Academic achievement described here concerns adaptations and evolutionary potentials of organisms from different latitude populations experiencing different degrees of environmental constraints. Specifically, the main objective of my study was to verify if seasonal time constraints shape life history and biotic interactions in individuals from different populations along a latitudinal gradient. Because high latitude populations are exposed to strong directional selection in traits that affect fitness, the second main objective was to verify whether the length of seasonal time window available for development and reproduction shapes evolutionary potential across different latitude populations. The experimental approach used in these studies was that organisms were grown in temperatures and photoperiods simulating those in nature (novel method) as well as constant thermo-photoperiod, also called common-garden conditions. Common-garden experiments are frequently used for studying different kinds of adaptations across populations and environments. The aim of using two alternative methods was to confront the possible differences resulting from the weaknesses of both approaches (Pigliucci 2001). Hence, growing individuals from different latitudes, including those situated in peripheral high- and low latitudes as well as central core populations in both simulated native and common-garden conditions gives comparable results and strong inference on species adaptation and evolutionary potential.

An organism used in all experiments was a damselfly *Lestes sponsa*. This is excellent species for answering questions on seasonal adaptations. The damselfly has a broad geographic distribution and is strictly univoltine (one generation per year) which facilitates to measure traits that are selected for seasonal adaptations in life history and biotic interactions. Individuals overwinter in egg stage and hatching takes place during following spring. Imago emerges during early summer (Johansson et al. 2010).

Below I present detailed hypotheses and results of the five articles constituting academic achievement.

1. **Śniegula S**, Gołąb MJ & Johansson F 2016 A large-scale latitudinal pattern of life-history traits in a strictly univoltine damselfly. Ecological Entomology 41: 459-472.

The first hypothesis stated that there will be negative relationship between insect size and latitude – the higher latitude, the smaller body size. The size-latitude relationship will be visible across all developmental stages: egg, larval and adult stage, and, as a result of directional selection on the trait, the relationship will have strong genetic background. To verify these hypotheses, I first sampled adult damselflies from a dozen of natural European populations between the latitudes 67°N-43°N. To check individual- and population specific environmental and genetic bases of the trait, I grew and measured peripheral high-, central core- and peripheral low latitude populations in simulated native and common-garden conditions. Note that comparison of data originating from natural field and laboratory conditions is rarely found in scientific literature mostly due to logistical reasons. Comparing results from both approaches allow to confront both methods and bring more general conclusions (Pigliucci 2001).

Adult sampled in nature showed negative linear size-latitude relationship: the lower the latitude, the bigger adult body size. The same trend was found in individuals grown in laboratory conditions in both simulated native and common-garden conditions. This supported strong population-specific genetic bases of adult size. Contrary to expectations, egg size did not parallel adult size: eggs from high latitude were the biggest. This suggests a trade off between investment in egg number and egg size which might be crucial for high latitude populations to survive long and harsh winters.

The results presented above have a broader evolutionary-ecological implications. In ectothermic organisms, body size is population specific and depends on the external conditions that these organisms experience during evolutionary time scale. However, in organisms with complex life cycles body size does not have to be linearly association with environmental gradients, e.g. thermal gradient, when different developmental stages are considered.

2. **Śniegula S**, Gołąb MJ & Johansson F 2016 Time constraint effects on phenology and life history synchrony in a damselfly along a latitudinal gradient. Oikos 125: 414-423.

The next studies concerned synchronization of phenological events along a latitudinal gradient. In line with theoretical expectations (Gotthard 2001), the hypothesis stated that high latitude damselflies have more synchronous hatching and emergence than individuals from central and low latitude populations. This is because increased synchrony of these two phenological events should be selected for in regions with brief growth and breeding seasons. Since life histories of temperate populations are shaped by temperate and photoperiod (two primary environmental cues) (Bradshaw and Holzapfel 2007; Angilletta 2009), both proxies were considers when testing the hypothesis.

The experimental material originated from high- (67°N), central- (54°N) and low latitude (43°N) populations of *L. sponsa*. Eggs produced by field collected adult female were incubated in three separate climate incubators. Each incubator was programmed to simulate natural thermo-photoperiod for every population sampled. Another incubator was set with constant thermo-photoperiod (common-garden conditions) and was shared by the three latitudes sampled. The common-garden setting mimicked temperature that every population experience for at least several hours during the growth season. The photoperiod reflected the longest day length at the mid-latitude across sampled latitudes.

In agreement with the prediction, individuals from different latitude populations subjected to simulated native thermo-photoperiods showed a positive correlation between the synchrony of phenological events and the degree of latitude. In contrast to the damselflies from low latitudes, those from high latitudes confirmed to hatch and emerge with the highest synchrony. This supported the notion that northern environment characterized by the shortest and coldest breeding season selects for genotypes with high-level synchrony. Intriguingly, individuals grown in common-garden settings, hence foreign or novel conditions, expressed the opposite trend with high latitude damselflies showing the least synchronized hatching.

To summarize, the results confirm that brief growth season with suboptimal ambient temperatures favours individuals with synchronized phenological events. Nonetheless, presence of phenotypic plasticity in these fitness related traits might be adaptive in a face of rapid environmental changes, e.g. advanced spring arrival driven by global climate change.

3. **Śniegula S**, Gołąb MJ, Drobniak SM & Johansson F 2016 Seasonal time constraints reduce genetic variation in life-history traits along a latitudinal gradient. Journal of Animal Ecology 85: 187-198.

Up to know, the results and conclusions were based on fitness related traits without considering levels of genetic variations of these traits. Genetic variation is a key for evolutionary changes (Stearns 1992), hence it allows to determine and quantify the evolutionary potential of traits in focus. In previous articles I showed that populations of the same species differed in trait values and this differentiation had both the environmental and genetic backgrounds. Similarly, as an effect of population size, gene flow and environmental conditions, populations might differ in the amount of evolutionary potential (Eckert et al. 2008). Based on this, I predicted that high latitude populations will show the lowest genetic variation in life history traits. This is because these populations have been going through strong selection on these traits, are represented by small population sizes and low between-population gene flow.

One of the traits I measured during this experiment was larval growth rate. This trait shapes insect size at emergence and breeding and hence is strongly connected to fitness. As in previous studies, the analyses were based on data from experiments where high- central- and low latitude damselflies were grown in simulated natural thermo-photoperiods and in constant common-garden conditions.

The results hold the expectation since damselflies from high latitudes exposed to native thermo-photoperiods expressed lower genetic variation of growth rate when compared to central and low latitude damselflies. The fastest growth of northern individuals confirmed strong selection on the trait that resulted in lowest evolutionary potential of this fitness trait. Intriguingly, when larvae were kept in non-native conditions (common-garden experiment) the results did not go in line with those obtained from simulated native conditions experiment.

To sum up, the results enclosed in this part of the academic achievement indicate that the evolutionary potentials of key life history traits depend on environmental condition that populations have experienced and on the evolutionary history that individuals from these populations have gone through. In order to predict the effects of the ongoing environmental changes on the evolutionary responses in natural populations it is advised to test these populations across a wide range of conditions that these populations might experience in the future. Inclusion of geographic central core and peripheral populations could be crucial for working out general conclusion on species as a whole.

4. **Śniegula S**, Gołąb MJ, Drobniak SM, Johansson F 2018 The genetic variance but not the genetic co-variance of life history traits changes towards the north in a time-constrained insect. Journal of Evolutionary Biology 31: 853-865.

To this point I have dealt almost exclusively with single phenotypic traits (latitudinal differentiations in mean traits values and trait genetic variations). However, organisms are not collections of individual traits that evolve independently. Traits are functionally and genetically linked and ecological forces that cause selection act on group of traits simultaneously. If traits are functionally linked, correlational selection can bring positive fitness effects (Futuyma 2013). For example, in insects female size positively correlates with number of progeny produced (Honěk 1993). It should be mentioned that environmental variation can influence the degree of genetic correlation (Wood and Brodie 2015) and this in turn can impact evolutionary potential of individual traits. Knowing that seasonally time constrained high latitude populations are exposed to strong selection on life history traits, I predicted that these functionally linked characters should show the strongest genetic correlations. For instance, postponed or delayed hatching will result in shorter larval development time and faster growth until emergence, faster growing larvae will show shorter development time until emergence. I also assumed that genetic associations between traits will change when the growth conditions differ (simulated natural vs. common-garden conditions).

When kept in simulated native thermo-photoperiods, all populations exhibited strong positive genetic relationship between hatching date and larval growth rate, negative relationship between hatching date and larval development time and negative association between larval growth and larval development time until emergence. Contrary to the prediction, I did not find differentiation in genetic correlations between high- central- and low latitude populations. The later result could be explained by the fact that these life-history traits are tightly connected by important trade-offs similarly in all populations and these connections would work in the same direction in this strongly time-constrained temperate species. Hence, it would be very costly to break these connections (and trade-offs) apart. For example, weak or no correlation of the timing of hatching and larval development time could result in low synchrony at emergence. Within-population asynchronous emergence could lead to problems in finding a partner that would eventually negatively affect reproduction success. Interestingly, different latitude populations exposed to constant temperature and photoperiod showed different pattern of traits genetic connections. On one hand this result supported the assumption that the environment can have biologically meaningful impact on genetic correlations. On the other hand, the discrepancy between results from the two experimental methods used indicate the limitations and drawbacks of studies where only common-garden conditions are used.

To conclude, this part of my research points that the degree and direction of natural selection on genetic correlations between important life history traits is similar across geographically distant populations. Yet, sudden environmental change, e.g. quick rise of ambient temperature, could brake these correlations and lead to independent evolutionary changes of individual traits.

5. **Śniegula S**, Gołąb MJ & Johansson F 2017 Cannibalism and activity rate in larval damselflies increase along a latitudinal gradient as a consequence of time constraints. BMC Evolutionary Biology 17: 167.

Until now I focused on two abiotic determinants, temperature and photoperiod, that shape seasonal regulation of life histories. However, there are other factors such as biotic interactions that might also play a key role in liming population existence. Within species predation, i.e. cannibalism, is one of these stressogenic interactions. Species experiencing seasonal time constraints and taking part in this kind of interactions are expected to show increased foraging activity and hence higher consumption of conspecifics. Preying on conspecifics let predators to acquire best food quality available and at the same time leads to reduced number of competitors (Elgar and Crespi 1992). The last hypothesis in this achievement says that damselflies living at high latitudes show higher cannibalistic rate than individuals from central and low latitudes. To control for the environmental effects on the within species interactions, damselflies were grown in simulated native as well as common-garden conditions.

The results from the simulated native conditions experiment supported the first assumption: *L. sponsa* from low- central- and high latitude populations showed positive linear relationship between cannibalistic rate and latitude degree. Hence, northern damselflies were the most aggressive towards conspecifics and consumed the highest number of potential competitors. This is likely an adaptive between-population differentiation in cannibalistic behaviour. High latitude insects try to compensate brief growth season by acquiring more resources that provision them with higher energy for growth and development. As mentioned above, higher growth and development lead to optimal timing of emergence and reproduction, i.e. individuals emerge and breed prior the end of the brief growth season. It came out that the pattern of within-species interactions is strongly regulated by the two environmental variables. The results from common-garden experiment differed significantly from those from simulated natural conditions experiment. Here, the relationship was non-linear. High- and low- latitude populations did not differ in the intensity of lethal interactions, whereas central latitude individuals showed the least intense within-species predation.

Results from the above described experiment indicate that organisms living in seasonally time constrained regions are exposed to selection on aggressive behaviour towards conspecifics. This aggressive behaviour is strongly cued by physical environmental variables such as temperature and photoperiod. These results also help to understand mechanisms that shape population dynamics and which environmental factors trigger differentiation in biotic interactions across distant geographic populations.

References

Angilletta MJ (2009) Thermal Adaptation: A Theoretical and Empirical Synthesis. Oxford University Press, New York, USA.

Bradshaw W, Holzapfel C (2007) Evolution of animal photoperiodism. Annu Rev Ecol Evol Syst 38:1–25.

Eckert CG, Samis KE, Lougheed SC (2008) Genetic variation across species geographical ranges: the central-marginal hypothesis and beyond. Mol Ecol 17:1170–1188.

Elgar MA, Crespi BJ (eds) (1992) Cannibalism: Ecology and Evolution among Diverse Taxa, 1st Edition edition. OUP Oxford, Oxford, England.

Futuyma D (2013) Evolution. Sinauer Associates Inc., Massachusetts, USA.

Gotthard K (2001) Growth strategies of ectothermic animals in temperate environments. In: Environment and animal development: genes, life histories and plasticity. Bios Scientific Publisher Limited, Oxford, UK, pp 287–303.

Honěk A (1993) Intraspecific variation in body size and fecundity in insects: a general relationship. Oikos 66:483–492.

Johansson F, Sniegula S, Brodin T (2010) Emergence patterns and latitudinal adaptations in development time of Odonata in north Sweden and Poland. Odonatologica 39:97–106.

Pigliucci M (2001) Phenotypic Plasticity: Beyond Nature and Nurture, First Edition. The Johns Hopkins Univ. Press, Baltimore, USA.

Stearns SC (1992) The evolution of life histories. Oxford University Press, New York, USA.

Wood CW, Brodie ED (2015) Environmental effects on the structure of the G-matrix. Evolution 69:2927–2940.

5. Remaining scientific activity

5.1. Period before obtaining the doctoral degree

Prior obtaining doctoral degree my research focused mostly on dragonfly and damselfly (Odonata) distribution in West Pomeranian Province (P23-25 and P30) and southern Poland (P20-22). Specifically, in these publications I presented a list of odonatofauna in a dozen or so biotopes situated on a former Soviet military training ground surrounding the town Borne Sulinowo. It is worth to mention that at these sites I recorded a number of protected by law species of dragonflies and damselflies, among which some are also place on Polish Red List. This proves high naturalness of these biotopes. For example, in one dystrophic late I observed numerous population (at least thousands of flying individuals) of the smallest European damselfly, *Nehalennia speciosa*, which, besides being protected and placed on Red List, has a zonal protection. This is actually the only invertebrate species in Poland that has this kind of protection (P30). I was also involved in a project on occurrence of damselflies in oxbows of upper Wisła: protected *Sympecma paedisca* and congeneric *S. fusca* (P21), as well as odonatofauna of Pieniński National Park in southern Poland (P20). I also co-authored faunistic note on new sites of *Cordulegaster bidentata* – a dragonfly species that lives in mountainous streams and is sensitive to anthropogenic impact.

I gathered collections and data on odonatofauna of north-western Canada (P29) and northern Sweden (P26-28). For example, in Canada I found a new site of Holarctic *Somatochlora sahlbergi* – an intriguing dragonfly species that in North America lives above 64°N (P29) only, and is probably sensitive to global climate change, but the evidence for this is weak due to species-specific habitat preferences. In northern Sweden I recorded new sites of the damselfly *Coenagrion pulchellum* and dragonfly *Somatochlora flavomaculata*. This records filled a gap of knowledge about northern distribution of European odonates and moved the geographic distribution of these two species couple of hundreds of kilometres towards the Northern Pole (P27).

During a Master degree studies in Umeå University in Sweden I undertook research on adaptations of ectothermic organisms to harsh environmental conditions in high latitudes. Data collected in natural field conditions as well as during laboratory experiments allowed me to write and defend Master thesis.

The following research on Odonata species characterized by different life history strategies (species with different life cycle durations, different timings of hatching and emergence and different stages during which winter diapause develops) set off my independent doctoral project at the Institute of Nature Conservation PAS in Krakow. I sampled the experimental material from Sweden and Poland. The results from several laboratory and field experiments hold two main hypotheses enclosed in my doctoral project: (1) that photoperiod, which is specific for particular latitude, is an important environmental cue regulating life history traits in organisms with complex life cycles (P13, P15, P17-19 and P12, which is not included in the thesis) and (2) that presence of counter-gradient variation lead organisms from different populations to expresses similar values of phenotypic traits despite experience different environmental conditions (P12, P17 and P18). This research work was granted by The

Ministry of Science and Higher Education (P13, P15 and P17) and *Worldwide Dragonfly Association* (P12).

Change in behaviour is usually first response to environmental variation. Part of my research was focused on behavioural studies of mobile and agile insects, adult damselflies in particular. During field experiments, I recorded different behavioural traits in response to habitat change. I also checked which of these traits correlate with each other, and if so, to what degree they correlate. Moreover, I studied breeding behaviour in the damselfly from the genus *Calopteryx*. Part of results from these studies were published prior I obtained a doctoral degree (P14 and P16).

5.2. Period after obtaining the doctoral degree

After defending my doctoral dissertation I continued my work at the Institute of Nature Conservation PAS in Krakow. I carried over my research on life history traits in insects from distant geographic localities. In one of latest papers (P7) I showed that mortality in *L. sponsa* is strongly shaped by larval development time: the shorter development time (and faster growth rate), the higher larval mortality. Yet, faster development and growth seem to have positive effects in populations that experience seasonal time constraints. This is with regard to individuals that hatch later in the season, or that live in regions with limited time available for development and breeding. Hence this article illustrate a negative trade-off between development rate and mortality rate that may eventually lead to fitness decrease.

During a post-doctoral stay in Catholic University of Leuven, Belgium, I examined whether and to what degree additional environmental stressors like heat waves and pesticides affect damselflies life history and physiology across northern and central Europe populations (P5). Hence, besides seasonal constraints, individuals were exposed to anthropogenic stressors. I analyzed (1) if heat waves experienced during egg stage affect larval and adult life history and physiology and (2) if pesticide experienced during larval stage impacts adult life history and physiology in terms of fat content (=energy storage) and investment in muscle mass. In other words, I checked whether there were latent or carry-over effects of different stressors across developmental stages. Indeed, the results supported presence of carry-over effects in an organism with complex life cycle. First, heat wave experienced during egg stage had a negative effect on adult fat content in individuals from central Europe. Larvae exposed to pesticides had slower growth, stored less fat and invested less into muscle mass at the emergence when compared to control group. Yet, there was no synergistic interaction between these two anthropogenic stressors on any trait measured. Interestingly, despite having faster growth, northern damselflies were no more sensitive to additional stressors than damselflies from the central Europe. In one case it was even opposite: contrary to central latitude insects, northern damselflies exposed to heat waves when in egg stage invested the same amount of resources into fat content and muscle mass at emergence as control group. All in all, the presented results highlight that multistressor studies should integrate across all life stages in order to capture cumulative effects of these stressors on life history and physiology in organisms with complex life cycles. What is more, multistressor effects might be population-specific and the end results could not agree with expectations.

Although life history and physiological traits are directly and indirectly linked to fitness, morphological characters could also have indirect effects on breeding success. Next part of the research verified a hypothesis on the allometry of anal appendages used by *L. sponsa* males for grasping the female prior mating (P6). In particular, I hypothesised that, across a large latitudinal gradient of the damselfly distribution, there is a larger investment in the anal appendages in individuals showing higher mating success. As expected, positive allometry between the length of grasping apparatus and overall body size was found in individuals from high latitude populations only. This results could at least partially explain why damselflies living at the Arctic Circle show higher number of mating than damselflies from lower latitudes (P6).

A collateral research project I was involved in was on mating behaviour in the damselfly *Calopteryx splendens*. Results from field observations indicated that territory defending behaviour of territorial males depends not only on the quality of the territory but also on interactions with conspecific competitors. I addition, changes in habitat quality caused by flooding could change males behaviour. These behavioural changes depend on males social status prior flooding. For example, individuals that invested great amount of energy for territory defending prior habitat change, paid for this by having lower mating success during and after habitat modification (P8).

The most recent studies concerned biotic factors that shape populations size and populations dynamics. The results from an experiment on three phylogenetically closely related damselfly species from the family *Coenagrionidae* demonstrated that these insects can detect presence of predators (in this case perch) in the surroundings by sensing predator smell (kairomones) (P2). Interestingly, every species responded differently in terms of egg survival and hatching dates to the presence of kairomones. Furthermore, individuals experiencing fish smell during very early larval stage expressed lower larval growth rate during later larval stages despite absence of kairomones. This shows that predators sharing the same habitat with potential prey might have colossal impact on prey population size and dynamics even in the absence of predator-prey physical contact. Another conclusion that arises from this experiment is that studies on predation stress should integrated across all life stages of prey that goes through complex life cycle. Focusing on just one ontogenetic stage, e.g. egg or larval stage, might blur final conclusions.

In a frame of my current grant project financed by National Science Centre (Opus), I have been doing extensive research on the importance of intra- and interspecific interactions of damselflies that share the same biotopes during egg and larval stage (freshwater habitats) as well as during terrestrial stage (adults). The species differ in life history characteristics and in the rate or range expansion towards the Northern Pole as a result of global climate change. Until know I have shown that *L. sponsa* larval interactions between individuals differing in size (effect of different dates of hatching) can strongly affect number of fitness related traits

(P1). Obviously, changes in individual fitness components can impact populations size and dynamics.

5.3. Plans for the future

In the approaching future I plan to continue my research plans enclosed in the grant project Opus (National Science Centre). I will focus on biotic and abiotic factors shaping population dynamics in species that move their geographic distributions to higher latitudes and species that are native to the north. In particular, I will check the direction and degree of within- and between species interactions at the northern edges of species distributions. I will extend my studies by evaluating the effects of species interactions on physiological responses. In other words, I will try to explain mechanisms that regulate population dynamics in organisms that represent important trophic level in freshwater and terrestrial ecosystems. The results and conclusions will be important for conservation, especially with regard to species with similar life histories and habitat preferences as those used in the project.

I will be involved in studies of mating behaviour in *Calopteryx splendens*. As part of a research group, we will focus on rather intriguing topic of insect personality. Individual differences in behavioural profiles have been reported in other taxonomic groups of animals, hence it will be interesting to study this phenomena in damselflies as well. Explaining the mechanisms that stand behind animal personalities will bring new insights in this field of science. Moreover, measuring traits that are connected to species migration and setting new populations (e.g. individual activity and boldness) over the contemporary species distribution will help in predicting possible consequences of rapid climate change.

In close future I will take part of international project granted by The Swedish Research Council (*Vetenskapsrådet*). The aim of the project is to study evolutionary potential of insects that are extremely sensitive to global climate change. Besides analysing quantitative genetic variation of life history traits, a cryptic or hidden genetic variation will be evaluated. This variation is expressed when organisms are exposed to sudden and unexpected changes in the environment, e.g. rapid temperature increase (heat wave). Results from this research project will improve and strengthen our forecasting on how individuals, populations and whole ecosystems will react to habitat disturbances.

While being involved in projects described above, I will expand my analytical workshop, e.g. statistical modelling in R environment, and improve the practical part in doing analyses of physiological traits. I also expect to author and co-author research articles that will be published in leading scientific journals. Finally, I plan to make my research findings widely available for public in a form of popular science articles.