SUMMARY

Life history strategies in organisms with complex life cycles such as insects are influenced by physiological variations and environmental factors. Yet, many of these strategies have not been explored. In my thesis, I studied how direct and indirect antagonistic interactions in combination with other ecological stressors such as seasonal time constraints and warming temperature shape growth and developmental strategies through physiological responses in two damselfly species with different life cycle characteristics. To achieve this, four separate studies were conducted:

In **Paper 1**, I investigated if non-consumptive predator effect (NCPE) of chemical cues released by a freshwater top predator, perch *Perca fluviatilis,* experienced during juvenile stages, carried over and affected life history traits at emergence in the damselfly *Ischnura elegans*. For this, a fully-crossed experimental design was used, where either or both of egg and larval stages were exposed to the predator cues. To exclude direct consumptive effects, i.e. cannibalism, larvae were reared individually.

Predator cues experienced only during the egg stage increased larval mortality rate, but only until individuals reached the second week after hatching. However, larval exposition to NCPE decreased survival rate until emergence, and individuals that survived and emerged did so with delay. Finally, larval growth rate was negatively affected by NCPE during the egg stage, and the effect increased when the exposition continued through larval stage. These results show that non-consumptive predator effects experienced only during early developmental stages, including a brief egg phase, in potential prey can carry over and negatively affect adult fitness traits.

In **Paper 2**, I studied the impact of hatching phenology and seasonal time constraints on intraspecific interactions in a cannibalistic damselfly *Lestes sponsa*, and how these variables affected cross-metamorphic life history and physiological traits. Different hatching dates commonly lead to so called size-mediated priority effects (SMPEs), where early hatched larvae take competitive advantage over late hatched ones. I hypothesized that phenologically driven SMPEs will be strengthened by time constraints imposed by the length of the growth season, the latter negatively associated with latitude. I run a fully-crossed experiment where high- or central latitude *L. sponsa* larvae were reared in groups in native and non-native combinations of temperatures and photoperiods (hereafter, thermo-photoperiods). By manipulating damselfly hatching date, and this to reinforce SMPEs, I aimed to test whether early hatchers take advantage over late hatchers in terms of life history (survival, development time, growth rate and mass at emergence) and fitness-related physiological traits (immune function measured as phenoloxidase activity, fat content and protein content at emergence).

Early hatchers had the highest survival rate, fitting SMPE prediction, yet, with no differences across thermo-photoperiods and population origin. Similarly, SMPEs was found in mass at emergence (higher mass in early than late hatched larvae), but only in central latitude *L. sponsa* reared under native thermo-photoperiod (= weak time constraint). Other life history and physiological traits did not show SMPEs. Instead, these trait expressions could be explained by different trait responses to seasonal time constraints, i.e. SMPE were outweighed by seasonal time constraints. For example, when reared under high latitude thermo-photoperiod (= strong time constraint) damselflies adaptively decreased larval development time until emergence. Strong time constraints caused decrease in immune function, indicating cost and trade-off between development rate and immune function under time constrained situation. These results imply that SMPEs are trait dependent and only weakly shaped by seasonal time constraints.

The aim of **Paper 3** was to check if and how different hatching phenology reinforcing SMPEs, in combination with altered temperatures and presence or absence of NCPEs released from perch shape life history and physiology in a cannibalistic *Ischnura elegans* sampled from a central latitude population.

Comparably to *L. sponsa* (**Paper 2**), group-reared early and late hatched *I. elegans* showed clear SMPEs in survival rate until emergence and in emergence success, with neither temperature nor NCPEs affecting priority effects in these two traits. Nonetheless, high growth temperature generated SMPE in protein content that adaptively carried over to the adult stage. Other life history traits (development time, mass and growth rate) were affected by temperature and NCPEs, but showed no support for the SMPEs. For example, predator cues reduced larval growth rate and mass at emergence, but only under high temperature treatment. This result suggests that warming temperature may magnify the effects of predator-induced stress in prey, but that the increased predation stress may not affect intraspecific SMPEs in prey. Physiological traits (immune function and fat content) were fixed across all treatments, suggesting decoupling between life history and physiology in the study population. The results confirm that antagonistic interactions reinforced by SMPEs are an important factor which, by shaping survival during the juvenile stage and emergence success, can promote early emergence of merolimnic and cannibalistic ectotherms. The results further underline that intraspecific SMPEs are only weakly affected by temperature and NCPEs.

In **Paper 4**, I verified whether different hatching dates, temperatures and corresponding changes in number of generations completed per year (voltinism) affected life history and physiological traits in high latitude populations of *I. elegans*. Here, the SMPE was not reinforced; early and late hatched groups were reared separately, hence early and later hatchers did not interact and compete for resources.

In contradiction to previous studies (**Paper II** and **Paper III**), here early and late hatchers showed no difference in survival rate, likely because of minor larval size differences within each experimental group. Minor size differences between competing organisms might result with reduced cannibalism rate, which likely happened in this experiment. Warming temperature also did not affect survival. Yet, warming shortened larval development time until emergence and increased voltinism regardless of hatching date. Early hatched individuals that experienced elevated temperature showed higher investment in immune function which might be explained by relocation of resources from other physiological traits, e.g. energy reserves. The results suggest majorly adaptive phenotypically plastic responses in life history, including voltinism, and physiological traits to climate change in organisms exposed to time constraints, and support the importance of phenological shifts in a warming world for shaping these traits in insects.

The thesis underlines the importance of antagonistic interactions in shaping fitness traits in key merolimnic ectotherms with complex life cycles. The experimental findings support the assumption that predator cues experienced during the initial developmental stage carry over to adult stage in potential prey. Such NCPEs found in the current study might ultimately have negative consequences on reproductive success and fecundity in prey. The thesis also emphasizes that within population variation in hatching date can reinforce SMPEs, and that these priority effects might have large consequences on larval and adult fitness traits, which may translate into population dynamics. Nonetheless, other environmental factors such as seasonal time constraints and warming temperature can mediate fitness-related outcomes of the SMPEs. These results highlight that the impact of antagonistic interactions on ectotherms fitness traits is largely context dependent.