The influence of environmental changes and individual trait variability (phenotypic plasticity) on biodiversity and ecosystem stability

With the continuing burning of fossil fuels, the degree, rate and intensity of anthropogenic environmental changes are further increasing. Pollution, but also massive changes in land use and the emission of greenhouse gases lead to a severe loss of habitat structure, changes in habitat chemistry and even climate change. Anthropogenically released CO_2 accumulates in the global carbon cycle and is anticipated to imbalance global carbon fluxes. For example, increased atmospheric CO_2 induces a net air-to-sea flux where the oceans take up large amounts of atmospheric CO_2 (i.e., leading to ocean acidification). Not only the oceans take up large amounts of atmospheric CO_2 but also freshwater carbon hydro-geochemistry is affected, giving rise to even higher amounts of pCO_2 in freshwater habitats. This development will, in the long run, harm ecosystems and can reduce biodiversity. Biodiversity is a major factor stabilizing ecosystems serving as a buffer against environmental perturbations. Biodiversity can be observed on all levels of biological organizations i.e. genetic, species and ecological. These general levels can be further subdivided, so that within one species not just different genotypes but also different phenotypes can be observed. This trait variability paired with phenotypic plasticity further complicates our understanding of how biodiversity contributes to ecosystem stability. Two scenarios are possible: 1) Phenotypic plasticity (trait variation) might increase the biodiversity of because organisms are adapted to exist under a range of changing conditions it allows for an optimal niche use. 2) Phenotypic plasticity (trait variation) might decrease biodiversity because it enables the plastic organism to exploit a wider niche space rather than allowing a specialization of different genotypes. We tested the influence of phenotypic variability on the genetic diversity in artificially composed populations subjected to natural (predation) and anthropogenic (elevated pCO_2) stressors. After isolating ten *Daphnia pulex* clones from a wild population, we performed a full-factorial experiment and tested these *Daphnia* clones and their reaction norm to four treatments (**control**: animals were cultured in control media M4 at norm pCO_2; **predator:** animals were cultured in control media M4 and norm pCO_2 but in the presence of *Chaoborus* kairomone enriched media; **pCO_2**: animals were cultured in M4 media with elevated pCO_2 (12,000 µatm) and **pCO_2 + Chaoborus**: where animals were cultured in M4 media with elevated pCO_2 (12,000 µatm) and *Chaoborus* kairomone enriched media). These clones showed distinct reactions norms (weak to strong expression of defensive neckteeth) to predation, so that there was an observable degree of trait variability within these clones. When additionally exposed to elevated $pCO_{2,}$ six out of the ten clones, were impaired in their ability to respond to *Chaoborus* cues, as we observed a reduced defense expression capacity and life history effects (i.e. smaller brood sizes). Based on their predator specific reaction norms (2 strong, 2 weak), we selected four clones and investigated treatment dependent changes of behavioral patterns using a custom designed 3D movement tracking system. While the analysis is still ongoing, preliminary results show that under elevated pCO_2 swimming speeding is significantly affected. This confirms that elevated pCO_2 has a clear effect on *D. pulex* behavior as well as morphological defenses.

We then wanted to test how phenotypic variability under these stressors affects an artificial *D. pulex* population. This population was composed of the ten clones with known traits. In mesocosms we exposed this artificial population to the four conditions described above but with three *Chaoborus* larvae as predators. Within one experimental trial we replicated each treatment six times and performed in total three experimental trials. We then analyzed the population composition after six weeks using microsatellites. We observed unexpectedly stable genotype distribution at the end of our experiments between treatments and replicates. Clonal diversity declined in all treatments. However, no treatment resulted in particularly lower or higher genotypic diversity in the *Daphnia* populations. We observed that the clones with an intermediate reaction norm outcompeted the clones with a strong reaction norm as well as the ones with no reaction. Furthermore, clones with large reaction norms, show decreased fitness in forms of increased mortalities, that we measured in our phenotyping experiment. Therefore, it appears that the generalists are outperforming the specialists, and the large reaction norms that are not needed in our experimental scenario, could incur trade-offs reducing overall organism fitness.

In conclusion, we could show that within a species phenotypic trait variability can greatly vary between genotypes. We provide evidence, that anthropogenic disturbance (CO_2) can interfere with a species reaction to natural threats (predation). However, under our experimental conditions the treatments did not lead to clonal extinction but to a dominance of different clones. Being flexible did not guarantee higher fitness. In fact, we found that clones that show intermediate reaction norms survive and reproduce at a higher rate than clones at the end of the reaction norm spectrum. Apparently, being average seems to be the cost-benefit optimized solution to the here tested moderate scenarios. In the future, we will repeat the here performed experiments with a higher predator density in order to increase the predation pressure and determine if the population composition changes.

Publications

Laumen, C., Lampert, KP, Tollrian, R., Weiss, LC, (In prep.). Genetic diversity and trait diversity in experimental Daphnia pulex communities affected by predators and elevated CO2

Laumen, C., Lampert, KP, Tollrian, R., Weiss, LC, (In prep). Sensory impairment by elevated levels of CO2 leading to modified behavioral defenses in Daphnia pulex