DZG 2024
Stuttgart, Germany

Satellite Symposium
Subject Group Ecology

Adaptation to global environmental change

Phenotypic plasticity & trait variability in individuals, species and communities

Tues | September 10th 2024
09.00 am – 2.30 pm

Keynote Speaker

- **Philipp Lehmann** | University of Greifswald
- **Frank Melzner** | GEOMAR
- **Florian Menzel** | University of Mainz
- **Sabine Nooten**| University of Würzburg
- **Alexander Wacker** |University of Greifswald

Synopsis

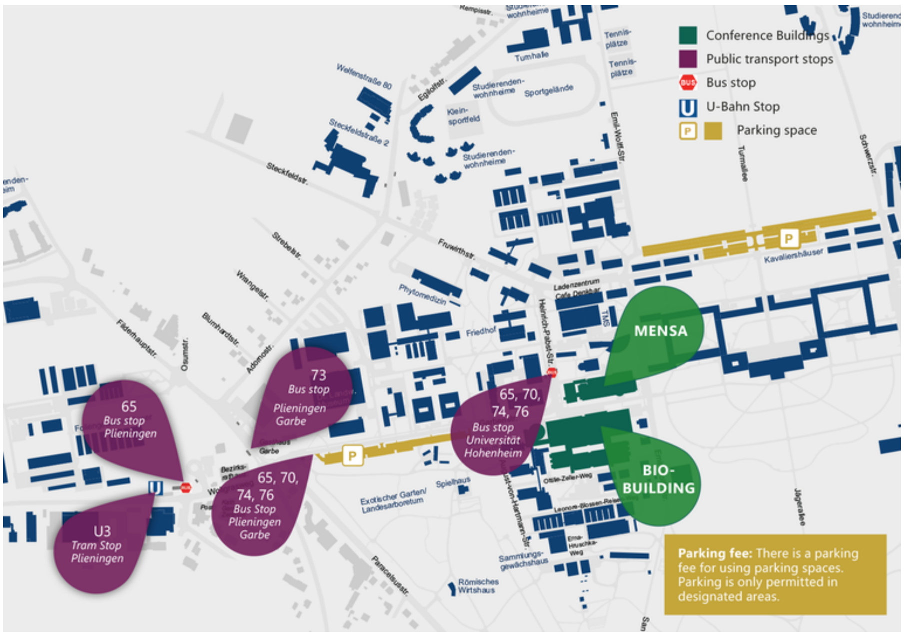
Climate change, deforestation, urbanisation and a multitude of further human disturbances impact environments across the globe. Animals need to adapt to survive, and phenotypic plasticity and trait variability are key prerequisites.

This symposium aims to provide an interdisciplinary platform to bring together current insights on morphological, developmental, physiological and behavioural plasticity and variability of traits. We aim to explore and discuss how animals may keep pace with ever more rapidly changing environments in the future.

Venue

The Symposium will take place as satellite of the 116th Annual meeting of the German Zoological Society (DZG) in Hohenheim on **Sept. 10th, 2024**.

We look forward to welcome you at the University of Hohenheim in the **Bio Building, Lecture Hall HS B1** (see map below). We are pleased to offer a selection of tea and coffee during the breaks for your convenience. To help us reduce waste and conserve resources, we kindly ask that you **bring your own cup**. For lunch, the Mensa, conveniently located right in front of the Bio-Building, offers a variety of meals. Please note that the Mensa only accepts payment by card. We hope you will enjoy the Satellite Symposium!



ORGANIZERS

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Programme

TIME	*MIN*	*SPERAKER & TITLE*
8:30- 9:00	*30*	***Registration***
9:00 - 9:05	*5*	***Welcome***
9:05 - 9:35	*30*	***Frank Melzner*** Impacts of ocean warming on coastal communities: long-term mesocosm experiments to understand acclimation limits
9:35 - 9:50	*15*	**Margot Deschamps** Role of heatwaves in facilitating marine biological invasions: *Hemigrapsus sanguineus* larvae as a study case
9:50 - 10:05	*15*	**Luis Giménez** The role of Intraspecific trait variation in driving post-metamorphic survival: implications for recruitment in open populations.
10:05 - 10:20	*15*	***Wenke Krings*** The influence of marine and freshwater acidification on the tooth composition of gastropod radulae
10:20 - 10:40	*20*	**Coffee break**
10:40 - 11:10	*30*	**Alexander Wacker** Daily drivers influencing animal performance—or—how aquatic animals can perform under variable temperature conditions in a changing world
11:10 - 11:25	*15*	**Gabriela Torres** Osmotic stress as boundary to the conquest of the Baltic Sea by an introduced species: the Asian brush-clawed crab *Hemigrapsus takanoi* as example
11:25 - 11:55	30	**Phillipp Lehmann** Integrative biology of seasonal adaptations: developmental plasticity, microclimate, seasonal niche evolution
11:55 - 12:40	*45*	*Lunch break*
12:40 - 13:10	*30*	**Sabine Nooten** Environmental change and insects: effects on species, traits and communities
13:10 - 13:25	*15*	**Matthew E. Nielson** Plasticity in a boring future: the consequences of reduced environmental variation
13:25 - 13:40	*15*	**Carolina Ortiz-Movliav** Surviving at the edge: Physiological mechanisms and gene expression patterns in a latitudinally range-expanding spider
13:40 - 14:10	*30*	***Florian Menzel*** Global change effects on insects: from cuticular hydrocarbons and drought resistance to behaviour and community
14:10 - 14:30	*20*	*Final discussion and closing remarks*

Abstracts

Invited Talks

Impacts of ocean warming on coastal communities: long-term mesocosm experiments to understand acclimation limits

Melzner, Frank

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Using the Kiel Outdoor Benthocosm (KOB) facility, we have explored long-term coastal community responses to climate change. KOB allows for the development of complex marine shallow water communities via early life stages that are continuously pumped from Kiel Fjord into experimental tanks where they can settle. Within tanks, we can modulate temperature dynamically to create diverse ocean warming scenarios. Our recent research has focused on how the most important reef/meadow forming foundation species (e.g. mussels, macroalgae, seagrass) respond to simulated climate change. Here I will present experimental results that indicate that simulated winter climate change can lead to accelerated body mass loss in mussels and, surprisingly, their predators (sea stars). Here, sea stars did not increase predation rates and suffered from reduced nutritional content of mussels, with potential negative implications for reproduction in the following spring. Simulating summer heat waves, we exposed mussel/macroalgae and seagrass communities to varying summer heat waves intensities to titrate lethal thermal limits during seasonal thermal acclimation. We found that sublethal heat stress accumulates exponentially with temperature once critical temperatures are reached, leading to high mortality in some species and indicating a limited capacity for acclimation during extreme summer heat events. While RCP 4.5 like-scenarios led to limited ecosystem change, RCP 8.5 like-scenarios led to severe ecosystem change with strongly reduced productivity of autotrophic foundation species. I will discuss implications of these findings for studying acclimation capacity of ectotherms and highlight the usefulness of the KOB facility to study rapid evolution from standing (beneficial) genetic variation.

Daily drivers influencing animal performance – or – how aquatic animals can perform under variable temperature conditions in a changing world

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Temporal heterogeneity of the environment is critical for individual performance, population growth, interactions among populations, and thus community structure. To date, most studies consider only the influences of changes in the average of single environmental factors, such as temperature, rather than considering that changes are not just shifts in the mean, but are actually superimposed by daily and sometimes extreme fluctuations. I will present some conceptual examples of our studies on aquatic invertebrates dealing with temperature fluctuations using an interplay of field work, laboratory experiments and measurements.

Integrative biology of seasonal adaptations: developmental plasticity, microclimate, seasonal niche evolution

Loke von Schmalensee[1], Pauline Caillault[1], Caroline Greiser[1], Olle Lindestad[1], Katrín Hulda Gunnarsdottir[1], Karl Gotthard[1], Philipp Lehmann[1,2]*

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Temperature influences the rate of most biological processes. Nonlinearities in the thermal reaction norms of such processes complicate intuitive predictions of how ectothermic organisms respond to naturally fluctuating temperatures, and by extension, to climate warming. Additionally, organisms developing close to the ground experience a highly variable microclimate landscape that often is poorly captured by coarse standard climate data. Here we show the results of several studies on Pierid butterflies from Sweden where we have explored seasonal plasticity and adaptation through field experiments, laboratory work, and citizen science data analyses.

We show that development rate, an important fitness trait, can be accurately predicted in the field using models parameterized under constant laboratory temperatures. Additionally, using a factorial design, we show that accurate predictions can be made across microhabitats but critically hinge on adequate consideration of non-linearity in reaction norms, spatial heterogeneity in microclimate and temporal variation in temperature. Further, by combining empirical microclimate and thermal performance data, we project development of individual butterflies in an exceptionally high-resolved natural microclimate landscape, demonstrating that differences among microclimates just meters apart can have large impacts on the rate of development and emergence synchrony of neighboring butterflies. We finally show that large differences in population dynamics between the two closely related and seemingly ecologically similar butterflies is driven by seasonal specialization, manifested as strategies that maximize gains during growth seasons and minimize harm during adverse seasons, respectively.

Environmental change and insects:
Effects on species, traits and communities

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Insects represent a large portion of global biodiversity. They perform key ecological functions and are sensitive to modifications in their environment. I am using insects as model organisms to study effects of climate change, land use and habitat features on species, functional traits and communities. I am interested in questions related to global patterns, and the way species traits and climate can influence local communities and key ecological processes. My research shows that there is an immense variety in the sheer number of ants across the globe. At smaller scales, insect communities are influenced by land use types and habitat features. In climatically challenging environments, only species with a specific suite of traits persevere. Climate change has already led to an increase in severe weather events like heat waves, and these high temperatures severely impact the insect's physiology, with potentially far-reaching consequences. The rapid decline in insect biodiversity necessitates a better understanding of the interplay between species traits, their environment and ecological functions.

Global change effects on insects: from cuticular hydrocarbons and drought resistance to behaviour and community composition

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Climate change and other anthropogenic changes alter biotic communities world-wide. Everywhere, some species increase, while many others decline or go extinct. But which traits determine whether a species suffers or benefits from current developments? Here, I provide results from my own group, and a special issue I co-edited. Overall, generalist species are better off than specialists, and this concerns multiple niche dimensions. However, the strongest and most predictable trait shifts are driven by climate change: heat tolerance, drought tolerance, and thermal niche width. Especially drought resistance is vital, because a main problem of high temperatures is elevated desiccation risk. Drought resistance is mediated by the cuticular hydrocarbon (CHC) layer, which covers the body surface of insects and acts as physical barrier against water loss. Its ability to block water loss depends on its temperature-dependent phase behaviour. Insects can influence this through altering their chemical composition, e.g. during acclimation. Such plastic CHC changes alter CHC phase behaviour and this way enhance drought resistance. An individual's resistance depends on its species-specific CHC profile, but also on its plasticity (i.e. its ability to acclimate). These traits likely influence a species' prospect to cope with climate change. Another trait influenced by climate is behaviour. Our studies indicate that the behaviour of ants changes with temperature, but in species-specific ways. Behavioural traits determine the outcome of competitive interactions. Therefore, temperature changes may result in altered competitive hierarchies. Thus, climate change may strongly alter not only species-specific traits, but also community composition and biotic interactions.

Contributed Talks

Role of heatwaves in facilitating marine biological invasions: *Hemigrapsus sanguineus* larvae as a study case

Deschamps, Margot [1*], Giménez, Luis [1,2], Boersma, Maarten [1,3], Torres, Gabriela[1]

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Biological invasions, driven by climate change and human activities, pose significant threats to biodiversity and ecosystems worldwide. While much research has focused on the impact of rising mean temperatures on species invasions, the role of extreme weather events such as marine heatwaves, in facilitating biological invasions is less understood. This study investigates the response of larvae of the invasive Asian shore crab *Hemigrapsus sanguineus* to simulated marine heatwaves, examining the effects of varying heatwave intensity (current heatwaves: 18 °C and 21 °C, and projected future heatwaves in the German Bight: 24 °C), duration, and timing of the onset on the survival, development duration, and growth rates. All heatwave components influenced larval performance, with complex and varied responses. Earlier and longer heatwaves had a positive effect on larval survival and development. By contrast, exposure to cold temperatures during extended times (i.e., absence of heatwaves, late heatwaves) resulted in larvae following an alternative developmental pathway, characterised by an extra stage before reaching the megalopa. When exposed to short or long heatwaves, larval responses could not be always predicted by the average temperature experienced during development. This underscores the inadequacy of predicting larval performance using mean temperature conditions alone. These findings suggest that heatwaves may enhance larval survival and performance, potentially promoting the spread and establishment of *H. sanguineus* in non-native habitats at the expense of its native competitors. Understanding species dynamics under the effects of heatwaves is critical for predicting the impacts of future marine heatwaves on invasive species success and ecosystem health in a context of climate change.

The influence of marine and freshwater acidification on the tooth composition of gastropod radulae

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Molluscs, a diverse group of invertebrates including snails, clams, and cephalopods, are significantly affected by ocean acidification. Previous publications show that this process, driven by increased CO_2 absorption by water, lowers pH levels and reduces carbonate ion availability, crucial for mollusc shell formation. Acidification weakens their calcium carbonate shells, impairs physiological functions, and affects survival and reproductive success. The vulnerability of molluscs to these changes can disrupt ecosystems and understanding and mitigating the impacts of ocean acidification is vital for preserving mollusc biodiversity and the health of environments.
In this study, we focus on the impact of acidification on the composition of radular teeth, which are used for loosening algae from surfaces during feeding action. Two model species, marine Littorina littorea and freshwater Planorbella duryi, were kept at 7.5 or 8.1 pH for 6 weeks and the properties of the radulae compared with the ones from the control group. First, the radular tooth wear was documented via scanning electron microscopy, revealing that the 7.5 and 8.1 radulae show heavier signs of wear. Afterwards, the elemental composition of the teeth was tested via energy-dispersive X-ray spectroscopy. We found, that the outer surfaces of the teeth from the control group contain high proportions of silicon and calcium in both species. The radulae from the 7.5 group, however, lacked high proportions of Si and the ones from 8.1 high Ca proportions. This was also documented via confocal laser scanning microscopy, which allows to document material heterogeneities. Using nanoindentation, we tested the mechanical properties, such as effective Young's modulus and hardness of the teeth materials. The surfaces of the 7.5 and 8.1 radular teeth were significantly softer and more flexible than those from the control group.
These results strongly indicate, that water acidification influences the feeding organ of Gastropoda. This potentially affects the survival and reproductive success under challenging conditions and drives further evolution of radula – which however awaits further investigations.

The role of Intraspecific trait variation in driving post-metamorphic survival: implications for recruitment in open populations

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Most ecological studies attempting to understand causes of population dynamics and community structure disregard intraspecific trait variation. We quantified the importance of natural intra-cohort variation in body size and density of juveniles for recruitment of a sessile marine organism, the barnacle Semibalanus balanoides. Barnacles are representative of species organised in metapopulations, i.e. as open local populations connected by larval dispersal. We tracked the individual growth and survival of a cohort of juvenile barnacles from two shores of North Wales. Barnacles settled as larvae in spring 2002 on previously cleared rock. The density of these new recruits was experimentally manipulated in June and randomly selected individuals were monitored from June to October to evaluate the role of barnacle size and density in predicting survival. In doing so we characterised density at three spatial scales (quadrat: $25cm^2$, cells within quadrats: $25mm^2$ and neighbourhood: number of neighbours in physical contact with the target barnacle). At all scales, variations in juvenile body size exacerbated the effect of density-dependent mortality on population size. While density-dependent mortality was very intense in the small sized individuals, large-sized individuals experienced very weak density-dependent mortality and showed high survival rates. Using the concept of "Jensen inequality", we show that important biases in estimations of survival, based on population size only, occur at high barnacle densities, where survival is low. Our study highlights the role of body size variation to understand dynamics of open populations.

Osmotic stress as boundary to the conquest of the Baltic Sea by an introduced species: the Asian brush-clawed crab Hemigrapsus takanoi as example

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The Asian brush-clawed crab, Hemigrapsus takanoi, is the most recently introduced decapod crustacean in the Baltic Sea. The successful establishment of this species, and the potential to expand its distribution range into the Baltic Proper, depends on the ability to endure the decreasing salinity conditions (from seawater to 2ppt) characteristic of these areas. Because temperature is increasing in the Baltic Sea, H. takanoi must face the challenge of low salinity in a warming environment. One of the physiological mechanisms that allows organisms to cope with low salinity is extra-cellular osmoregulation, but such capacity is strongly affected by temperature. The way in which temperature influences osmoregulatory capacity (OC) varies among species. We quantified the effect of temperature (18, 21 and 24°C) on OC of H. takanoi at different salinities (<1 to ≈32ppt), in two populations living in contrasting osmotic environments (1) the Baltic Sea (Neustadt), experiencing low salinities (10 - 15ppt) and (2) the North Sea (Sylt), experiencing full strength seawater (32ppt). Crabs from both populations showed high OC which increased towards lower salinities maintaining the haemolymph osmolality at a fairly constant level down to 5 – 10ppt. However, populations differed in an important aspect: in crabs from Sylt, the OC exhibited at low salinities decreased from high to low temperatures while in those from Neustadt the OC at low salinity was consistently high, irrespective of temperature. The pattern exhibited by the population of the low salinity habitat (Neustadt) is adaptive because physiological functions must be performed under a wide range of temperatures. It remains to be elucidated if the differences between those two populations reflect long-term acclimation to low salinity or genetic variation. However, these differences highlight the adaptative value and thus the persistence of the Baltic population and points towards a possible expansion into the Baltic Proper.

Surviving at the edge: Physiological mechanisms and gene expression patterns in a latitudinally range-expanding spider

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The European wasp spider *Argiope bruennichi* has exhibited an unusually rapid latitudinal expansion from the Mediterranean to the Baltic states and Scandinavia over the past century. This expansion outpaces regional warming trends due to climate change, suggesting an adaptive response to novel environments, rather than the simple tracking of optimal climate conditions. In particular, populations at the expanding edge in northern Europe face greater seasonality and colder winters, presenting a unique opportunity to study genetic and phenotypic adaptations to cold stress. This study aims to elucidate the molecular and metabolic mechanisms underlying the successful colonization of colder habitats by edge populations compared to the native core populations. We used a reciprocal transplant common garden design with spiderlings from core and edge locations. We quantified the degree of local adaptation and phenotypic plasticity at the edge relative to the core populations by assessing their differential gene expression and metabolic profiles. Our results strongly support the hypothesis that edge populations are locally adapted to colder winter conditions. Edge populations showed an increased expression of genes associated with cold tolerance. Fatty acid profiles further support these findings. Moreover, spiderlings from the edge showed higher survival probability in both winter conditions. These insights into the adaptive strategies of *Argiope bruennichi* contribute to our understanding of rapid ecological expansions under climate change.