German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig
Puschstraße 4, 04103 Leipzig, Germany

sDiv working group meeting report
"Unicop"

***Summary**:* The UNICOP group completed its third face-to-face meeting in January 2024. The aim of this project is to build a mathematical and conceptual synthesis between foundational theories in evolutionary biology (i.e., the Price equation) and community ecology (i.e., modern coexistence theory). The group includes six researchers with diverse expertise across eco-evolutionary modelling, evolutionary theory, theoretical ecology, mathematical biology, and philosophy of science. From 15-19 January, group members built upon work from two previous meetings and developed two inter-related avenues of theory from group discussions, break-out sessions of mathematics, writing, and coding. By the end of the meeting, the UNICOP group made progress toward two novel and interesting insights towards the unification of modern coexistence theory and the Price equation. Since this meeting, group members have been working toward publication of these results.

The group is very grateful for sDiv support, which was excellent throughout the course of the week-long meeting. The meeting was facilitated by the flexibility of sDiv, and the resources available for holding discussions and working through modelling and theory ideas and coding in comfortable and productive environment. Organised lunches and dinners facilitated teamwork and reflection on research progress, and technological resources at sDiv made it possible to include one UNICOP member remotely. The UNICOP group also benefitted from conversations with multiple research group members at sDiv.

Research: The third meeting of the UNICOP working group continued to build off of the paths established in its first and second meetings. The meeting produced new theory and modelling for (I) integrating modern coexistence theory (MCT) into eco-evolutionary models and (II) building a unified bridge between the Price equation and ecological theory.

(I) A central focus was the integration of modern coexistence theory into eco-evolutionary models, with a goal to bridge the gap between how community ecologists and evolutionary ecologists approach within-species and among-species variation. This study focuses on providing a novel theoretical framework that has three key aims: (1) Determining how intraspecific trait variation can be taken into account in MCT, (2) analysing how niche overlap and competitive difference depend on the means and variances of species trait distributions at any given time, and (3) analysing how the potential for evolutionary change affects the conditions for species coexistence. To achieve these aims, the group has built a two-species community model that includes intraspecific trait variation to analyse how this variation affects stabilising and equalising mechanisms of species coexistence. The model developed allows for intraspecific variation in traits and the existence of unimodal peaks of traits (i.e., morphs within species), modelling both population dynamics and evolution of trait means and variances. From this model, the group has derived MCT equations for niche overlap and competitive differences, now incorporating within-species trait variances, that can be used to predict species coexistence versus competitive exclusion. Results from this model provide

important insights into the general role of evolving trait variation on species coexistence. These results and the general model are being prepared for peer-review and publication.

(II) A second focus was on unification of fundamental evolutionary and ecological theory. This focus is related to (I), but approaches the focal aim of theoretical unification from a different perspective. Rather than applying eco-evolutionary models, this second focus attempts to derive fundamental equations of ecology and evolution from first principles in a similar manner to the original derivation of the Price equation, which is the fundamental equation of evolution from which other evolutionary models (e.g., in population genetics or quantitative genetics) can be derived. Attempting to discover a novel, more fundamental equation from which evolutionary and ecological models can be derived was always meant to be a high risk and high reward aspect of UNICOP. Some efforts were expended toward this goal in meetings 1 and 2, which ended up being dead ends. Nevertheless, the third UNICOP meeting appears to have potentially delivered a breakthrough for this conceptual unification. Communication with leading researchers, including at sDiv, suggests that there is promise to our finding, which is encouraging. Nevertheless, the implications of this work are far from clear, and there is ongoing discussion within the UNICOP group about the utility of results in this area. A pre-print is currently in preparation for this focus of research, which will then be followed by submission for peer-review.

In addition to (I) and (II), the UNICOP team are also developing some related work that is relevant to the project and facilitated by sDiv. It is expected that this related work will lead to additional publications, such as a publication on the nature of the covariance term in the Price equation and its interpretation.

Next steps: Work is ongoing to produce deliverables from this project in the form of manuscripts for publication. We anticipate that the timeline for deliverables for (I) and (II) will include completed manuscript drafts by autumn 2024. Subsequent work will then build on these efforts in attempt to benefit as much as possible from group efforts and insights gained from the first three meetings of the project. The UNICOP team has benefitted very much from the opportunity that sDiv has provided to explore new ideas and pursue novel and ambitious goals in developing theory. This project is jointly funded by the sDiv synthesis centre and Centre for the synthesis and analysis of biodiversity (CESAB). The next UNICOP meeting will be held in Montpellier, France during the summer of 2025.