From 2D Niches to Stress Response Pathways

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A species fundamental niche is the set of all environmental conditions that permit a species to sustain its population. In this work we develop a theoretical framework for linking niche shape to the coupling between underlying molecular stress response pathways, construct an apparatus for measuring 2D temperature-salinity niches, and map the 2D niche of 17 strains whithin the marine bacterial genus *Vibrio*. Observed niche shapes indicate that higher stress tolerance is correlated with stronger coupling between the two stress response pathways, potentially indicating a transition from passive to active stress tolerance.

I. Introduction

IN his often cited 1957 essay "concluding remarks", G. E. Hutchinson introduced the concept of a fundamental niche as an n-dimensional hypervolume, "every point in which corresponds to an environment which would permit the species... to exist indefinitely." [1]. Hutchinson considered whether 2D niche shapes, *i.e.*, the two-dimensional cross-section of a pair of environmental factors, could prove informative regarding the physiological response of an organism toward those factors. He deduced that independently acting factors should map out a rectangular fundamental niche, because the maximum tolerance to either factor is independent of the other, and supposed that interactions between factors could lead to more complex shapes.

Here, we extend Hutchinson's work to the niche shapes corresponding to 3 basic types of stress interactions: linear interactions leading to rectangular shapes, synergistic interactions leading to concave shapes, and antagonistic interactions leading to convex shapes. An analogous approach is widely used in multicomponent drug therapeutics [2], where it is known as isobolographic analysis [3].

Additionally, we develop a custom-made dual gradient apparatus, and map a cross-section of the fundamental niche for 17 marine bacterial strains within the genus *Vibrio* based on their temperature and salinity tolerance, which are prominent factors in Vibrio ecology, population dynamics, physiological stress response, and evolution [4,5]

II. Results

Only a narrow range of niche shapes was observed, corresponding to coupling between stress responses that varies between nearly independent responses to nearly linear interaction. Moreover, salinity and temperature tolerance were positively correlated with each other, and negatively correlated with the interaction strength. That is, strains with low tolerance displayed nearly independent stress responses, whereas more tolerant strains displayed more coupling between the stress responses.

III. Conclusion

Stress response is typically multifaceted, involving complex genetic networks. Often, even the identity of the elements comprising these networks is unknown, let alone their functions. In this work we have demonstrated that qualitative information regarding the coupling between such networks can be gleaned from the corresponding 2D niche, even in the absence of any detailed molecular knowledge.

We found that only a limited range of niche shapes is observed in our model system. It remains to be seen how general this result is -- the niches of many more organisms, across numerous environmental conditions need to be mapped before general conclusion regarding the dynamics, selection and evolution of niches can be drawn.

References

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