A Community Unknown

Mapping the Environmental Drivers and Community Structure of Abyssal and Hadal Life in the Nova Canton Trough

Author: Landon Schumaker

Contributing Institutions: University of Hawai'i at Manoa, Minderoo-UWA Deep-Sea Research Centre

Executive Summary

The hadal zone (depths > 6,000 m) is Earth's deepest, largest, and least understood biome. Our knowledge of the life it holds is severely limited. This project addresses this knowledge gap through an unprecedented, high-resolution survey of the Nova Canton Trough (NCT), a unique fracture zone in the central Pacific.

Using data from 97 baited lander deployments (from 2,700 m to 8,000 m), this study applied an advanced Joint Species Distribution Model (JSDM) for the first time in an abyssal and hadal ecosystem.

The primary finding is the discovery of a clear hierarchy of ecological drivers. As previously understood in literature, broad-scale environmental filters, primarily depth and temperature, determine if a species can be present in a given area. Once present, fine-scale seafloor topography (like ruggedness) and biotic interactions (like competition between predators) determine how abundant that species becomes locally.

This research moves beyond simple species lists to create the first predictive, high-resolution maps of life in the final frontier, revealing a complex "layered seascape" structured by both large-scale environmental pressures and fine-scale habitat partitioning.

The Challenge: Beyond "Point-in-Time" Science

The deep sea represents the vast majority of the biosphere, yet our understanding of its ecology is decades behind that of terrestrial or coastal systems. Historically, deep-sea sampling has been limited to sparse "point observations" from trawls or baited cameras. This approach can tell us what lives in one specific spot, but it fails to answer the bigger questions: How are these animal communities structured over vast areas? What environmental factors drive their distribution? And how do these species interact in the dark?

Without a predictive understanding of these ecosystems, we cannot effectively manage or protect them from the mounting pressures of climate change and potential resource extraction.

A Novel Approach With High-Resolution Modeling

This project targeted the Nova Canton Trough, a unique hadal-depth fracture zone. To move beyond "point-in-time" data, we deployed 97 baited landers, capturing high-definition video data across a steep depth gradient from the abyssal plain into the hadal trough (2,700 m to 8,000 m).

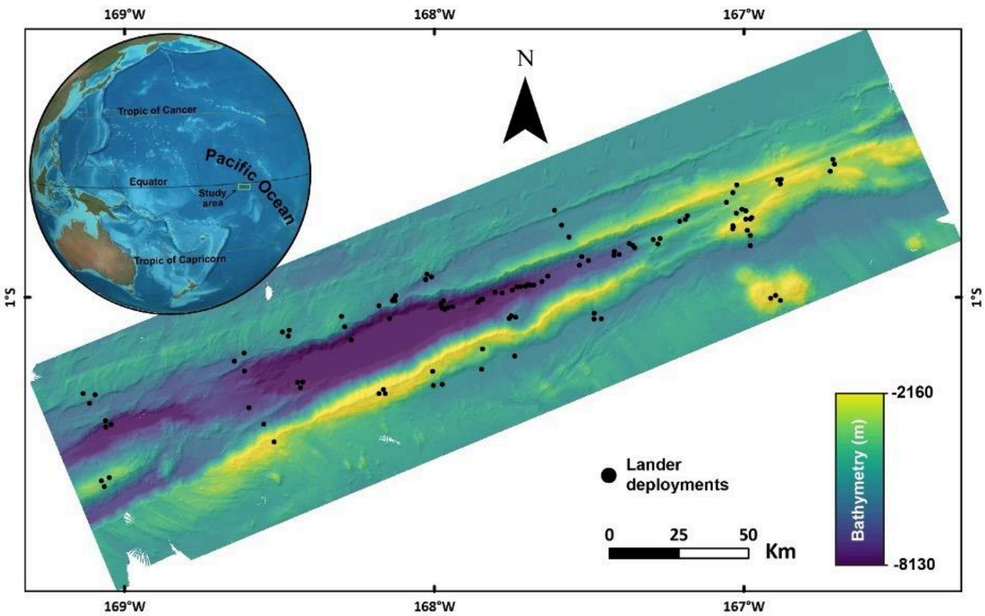

Fig 1: Multibeam bathymetry of the Nova Canton Trough, collected by the *RV Dagon*. Inset shows the location of the Nova Canton Trough within the Pacific Ocean.

The dataset of observed fauna was then analyzed using an advanced statistical framework known as a Joint Species Distribution Model (JSDM). Unlike traditional models that look at one species at a time, the JSDM analyzes the entire community at once. This model looks at species specific trait information, phylogenetic information, environmental variables and the raw baited camera data to determine its results. This allowed us to simultaneously identify the environmental drivers (depth, temperature, slope, ruggedness) for each species, quantify the influence of their traits (e.g., feeding strategy), and detect residual patterns of co-occurrence that suggest biotic interactions like competition or predator avoidance.

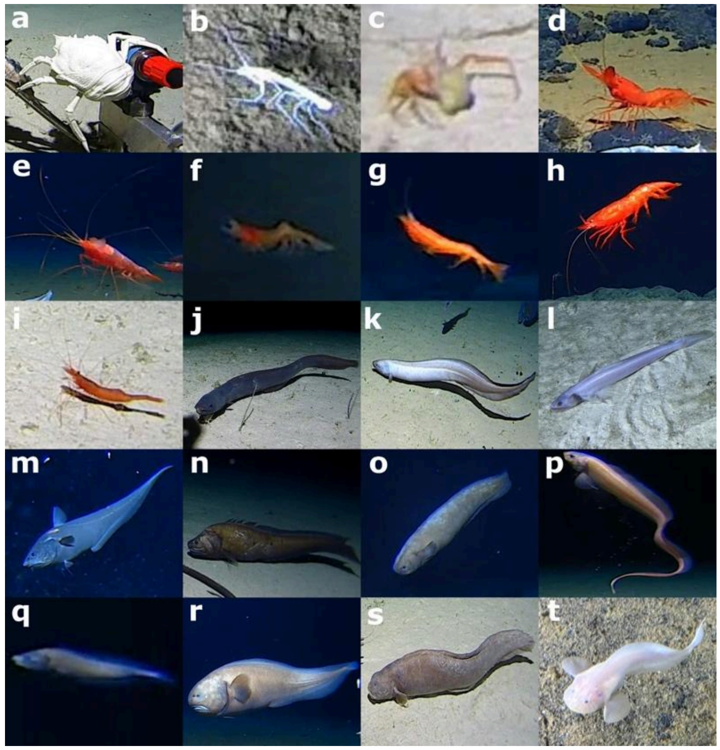

Fig 2 : Fauna included in study: a- Munidopsis, b- Ischnomesidae, c- Paguridae, d- *Cerataspis monstrosus*, e- *Benthesicymus crenatus*, f- Acanthephyridae, g- Heterogenys, h- Hymenodora, I- Nematocarcinidae, j- *Ilyophis arx*, k- *Ilyophis robinsae*, l- *Bathysaurus mollis,* m- *Coryphaenoides yaquinae*, n- Abyssoberyx, o- *Barathrites iris*, p- Porogadus, q- Leucicorus, r- Bassozetus, s- Pacycara, t- Pseudoliparis

Key Findings: A Hierarchy of Ecological Drivers

Our analysis revealed a clear and tiered system of ecological filters that structure life in the NCT.

Finding 1: A Two-Level Filter (Presence vs. Abundance)

The factors that determine a species simple presence are different from the factors that govern its abundance.

Presence tends to be set by physiology. The ability for a species to simply exist in an area is overwhelmingly dictated by broad-scale environmental filters. Depth (and its associated pressure) and temperature accounted for the vast majority of the variance. For example, the hadal snailfish (*Pseudoliparis*) is restricted to the trough by depth, while the abyssal rattail (*Coryphaenoides yaquinae*) is limited by a strong preference for specific cold-water temperatures.

Abundance is set much more by habitat and competition. Once a species is within its physiological comfort zone, its local success (or population density) is governed by a more complex set of fine-scale factors. Seafloor geomorphology (ruggedness, slope) and biotic interactions became significantly more important.

Finding 2: Spatial Segregation and a "Mosaic of Dominance"

The model revealed clear evidence of competition. For instance, the dominant abyssal rattail (*C. yaquinae*) and the dominant hadal snailfish (*Pseudoliparis*) showed a strong negative co-occurrence, actively segregating at the abyssal-hadal transition zone (around 6,000-7,000 m) to likely avoid direct competition. This partitioning creates a "mosaic of dominance" even within the abyssal plain, where the two most common predators, the rattail and the cusk eel (*Bassozetus*), showed inverse abundance patterns. Areas where the rattail was predicted to be highly abundant corresponded to low abundance for the cusk eel, and vice versa, suggesting they partition the seafloor to minimize competition.

Finding 3: Fine-Scale Habitat Specialization is Critical

Seafloor topography was a key driver of abundance. The shrimp family Nematocarcinidae, for example, was strongly associated with high-BPI and high-VRM values, meaning its abundance is highest in rugged, complex, and elevated terrain. Conversely, the eel Ilyophis arx showed a clear preference for flatter, simpler habitats and was most abundant in the shallowest parts of the study area.

The Result: The First Predictive Maps of a Hadal Community

The most powerful outcome of this model is the ability to generate continuous, high-resolution predictive maps of species distribution and abundance. These maps turn abstract data points into a tangible visualization of life.

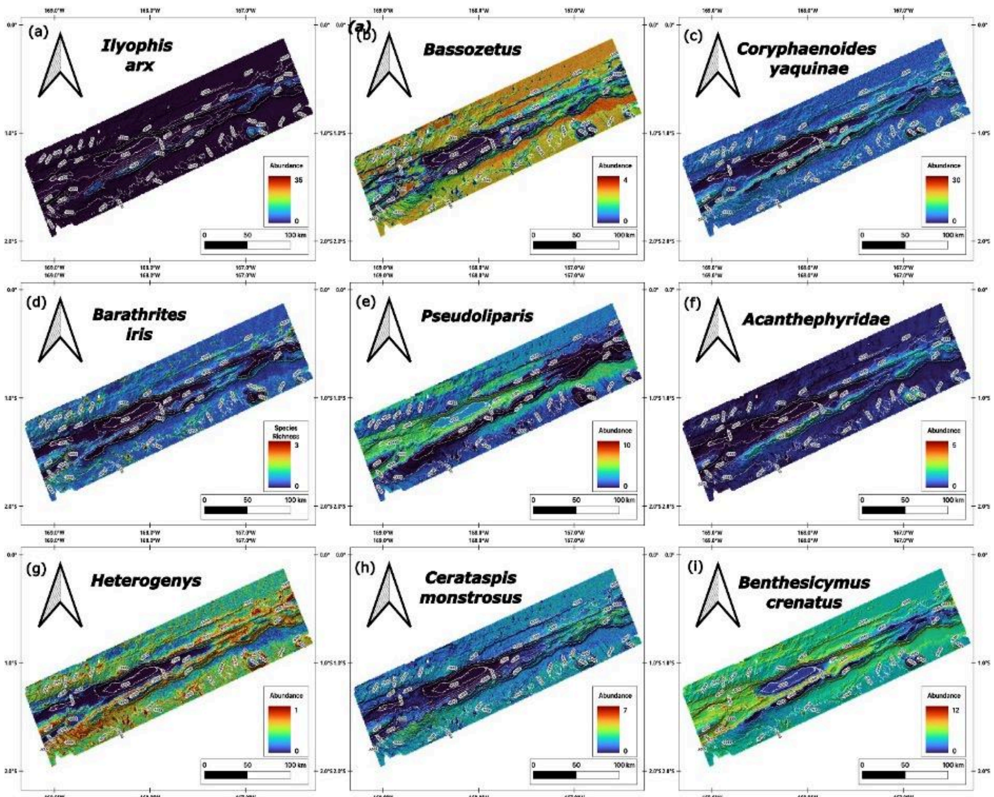

Fig 3 : This is a representative image of 9 abundance maps of some of the study species. Each individual map has large amounts of data that is analyzed and picked apart to understand what is structuring these communities.

These maps illustrate the "layered seascape," with shallow ridges (3,000-4,000 m) dominated by prawns (*Acanthephyridae*) and eels (*Ilyophis arx*); the abyssal plain (4,000-6,000 m) existing as a patchwork of the dominant fish predators (*C. yaquinae* and *Bassozetus*); and the hadal trough (>6,500 m) overwhelmingly dominated by the hadal snailfish (*Pseudoliparis*). The abyssal-hadal transition zone (6,000-7,000 m) emerges as a key area of mixing, where the deepest-living prawns (*Benthesicymus crenatus*) reach their highest abundance.

Broader Implications

This research represents a significant step forward in deep-sea ecology. It provides a methodological blueprint as the first successful application of a JSDM to a hadal ecosystem, offering a powerful template for modeling other unexplored trenches. Furthermore, it moves the field beyond descriptive species lists to a predictive understanding of why animals live where they do and how their communities are structured. Finally, these predictive maps provide a critical baseline for one of Earth's most vulnerable and least-understood ecosystems, which is essential for future management and conservation efforts.

References

Drazen, J. C., Leitner, A. B., Jones, D. O. B., & Simon‐Lledó, E. (2021). Regional Variation in Communities of Demersal Fishes and Scavengers Across the CCZ and Pacific Ocean. Frontiers in Marine Science, 8. https://doi.org/10.3389/fmars.2021.630616

Fahrig, L. (2020). Why do several small patches hold more species than few large patches? Global Ecology and Biogeography, 29(4), 615. https://doi.org/10.1111/geb.13059

Jamieson, A. J., Fujii, T., Mayor, D. J., Solan, M., & Priede, I. G. (2010). Hadal trenches: the ecology of the deepest places on Earth. *Trends in Ecology & Evolution*, *25*(3), 190-197.

Jamieson, A. J. (2011). Ecology of deep oceans: hadal trenches. *eLS*.

Jamieson, A. (2015). *The hadal zone: life in the deepest oceans*. Cambridge University Press.

Jamieson, A. J. (2016). Landers: baited cameras and traps. *Biological sampling in the deep sea*, 228-259.

Swanborn, D., Bond, T., Kolbusz, J., Cundy, M. E., Stott, M. B., Thomas, E. A., Kitazato, H., & Jamieson, A. J. (2024). Vertical zonation and environmental drivers of North-West Pacific abyssal and hadal mobile faunal communities. Deep Sea Research Part I Oceanographic Research Papers, 215, 104418. https://doi.org/10.1016/j.dsr.2024.104418

Wolff, T. (1959). The hadal community, an introduction. Deep Sea Research (1953), 6, 95. https://doi.org/10.1016/0146-6313(59)90063-2

Wolff, T. (1970). The concept of the hadal or ultra-abyssal fauna (No. 6). 17, 983. https://doi.org/10.1016/0011-7471(70)90049-5