Deep-sea ecosystem functions linked to biodiversity over the past 20,000 years

Biodiversity-ecosystem function (BEF) relationships have received much attention from ecologists, conservation biologists, and managers because they can be used to infer the consequences of losses of biodiversity on earth. Such losses are occurring rapidly due to biomass exploitation, habitat degradation, and especially global climate change. Since the mid-1990s, hundreds of experiments have manipulated the richness of plant or animal species or different combinations of functional groups in the laboratory and in the field to study the response of their ecosystem functions (e.g., biomass production and nutrient cycling) to changes in biodiversity. These experiments have reached a consensus and indicate positive and saturating responses of ecosystem functions to biodiversity. These results imply the importance of maintaining biological diversity and thus the functions and services of ecosystems (e.g., food production and climate regulation). Although much has been learned from these present-day, short-term manipulative experiments, information on how ecosystem functions react to long-term changes in biodiversity is still lacking. The logistical difficulties involved in maintaining long-term ecological monitoring represent the primary challenge in obtaining this information. Nevertheless, such understanding has become more important than ever because the earth's ecosystems and biodiversity are undergoing long-term degradation by human activities and climate change.

To understand long-term BEF relationships, Dr. Wei and his collaborators analyzed fossil records of microscopic deep-sea crustaceans called ostracodes. These records were obtained from the North Atlantic Ocean and cover the last 20,000 years. Due to the relatively continuous sedimentation that occurs in the deep sea, these records contain excellently preserved calcareous shells of fossil ostracodes and yield chronological information. To provide a link to present-day BEF relationships, Dr. Wei and his collaborators compared the fossil ostracode data to a decade-long census of deep-sea nematodes in the Mediterranean Sea. Nematodes are the most abundant metazoan invertebrates in the ocean, and they are also one of the most diverse taxa; the ocean is estimated to contain ~4,000 known species. They are tiny and have short generation times and high metabolic rates; thus, they process considerable amounts of energy through their growth and respiration. Both ostracodes and nematodes have well-developed functional traits, including their vertical position on the seafloor, feeding type, mobility, and morphology, and thus reflect additional aspects of biological diversity.

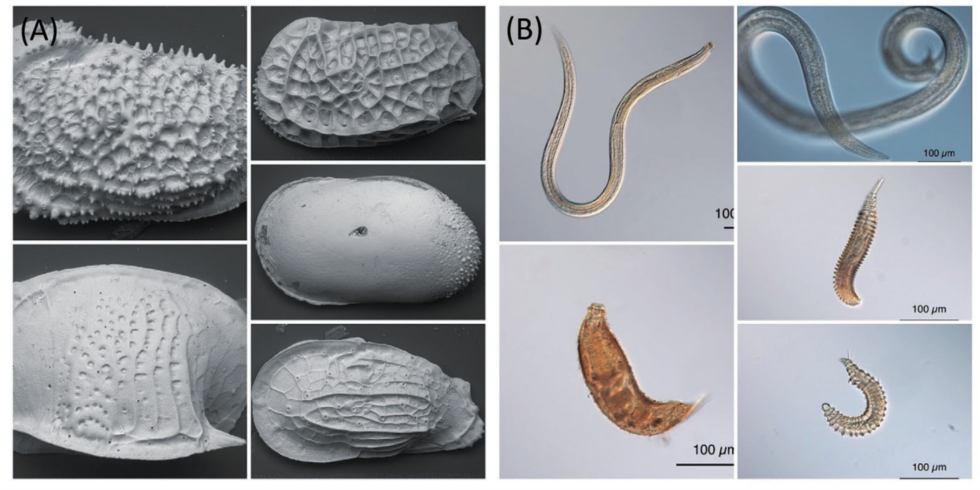

Figure 1. Microscopic views of deep-sea. (A) ostracodes and (B) nematodes. Image credits: Moriaki Yasuhara (University of Hong Kong), Jian-Xiang Liao (National Taiwan University).

The researchers used nematode biomass and the accumulation rate of ostracodes as proxies for ecosystem functions (e.g., productivity in an ecosystem). They compared the taxonomic and functional diversity of nematodes and ostracodes with these proxies of ecosystem functioning to investigate BEF relationships over decadal to millennial time scales and found generally positive, long-term relationships between biodiversity and ecosystem functioning, consistent with studies of BEF relationships based on present-day spatial analyses and short-term manipulative experiments. However, the deep-sea BEF relationships over longer time scales are much noisier than those inferred by modern observational studies. These relatively noisy BEF relationships suggest that environmental changes over decadal to millennial time scales may affect biodiversity and biomass independently, and these effects may be much stronger than the impacts of biodiversity on ecosystem functioning. This study suggests that abiotic factors are more important than biotic factors in shaping the patterns of biodiversity and ecosystem functions at macroevolutionary time scales because the changes observed over the decadal to millennial time scales investigated in this study are much shorter than the approximate lifespan of a species (1–2 million years). This work also implies that climate change may affect both diversity and ecosystem functioning over long time scales in the deep sea.

Reference
Moriaki Yasuhara, Hideyuki Doi, Chih-Lin Wei, Roberto Danovaro, and Sarah E. Myhre (2016). Biodiversity–ecosystem functioning relationships in long-term time series and palaeoecological records: deep sea as a test bed. *Philosophical Transactions of the Royal Society B: Biological Sciences, 371*(1694), 20150282. DOI:10.1098/rstb.2015.0282

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Quantum topological Hall effect in noncoplanar antiferromagnetic oxides

The integer quantum Hall (IQH) effect, first discovered in 1980 by von Klitzing [1] (a 1985 Nobel Laureate), is one of the most fascinating discoveries in physics. When a strong perpendicular magnetic field is applied to a two-dimensional (2D) electron gas (EG) at low temperatures, the Hall conductance is precisely quantized due to Landau-level quantization, and its values are an integer (NC) multiple of the fundamental conductance quantum (e^2/h). In 1982, Thouless (a 2016 Nobel Laureate) demonstrated that this quantization is directly connected to the topological property of the 2D bulk insulating states, characterized by a topological invariant called the Chern number (NC) [2]. Intriguingly, the conductance quantum number (NC) is exactly equal to the number (NC) of dissipationless chiral edge states in the 2DEG plane [Figure 1(a)]. The topological interpretation of the IQH effect implies that the effect can also occur in other time-reversal symmetry broken systems with a topologically non-trivial band structure in the absence of the external magnetic field, such as ferromagnetic topological insulators, leading to the so-called quantum anomalous Hall (QAH) effect [Figure 1(b)], as first proposed for a honeycomb lattice model in 1988 by Haldane [3] (2016 Nobel Laureate).

Due to its intriguing nontrivial topological properties and the potential application of its dissipationless edge states for designing low-power consumption electronics and spintronics, extensive studies have been performed to search for real materials to host the QAH effect. Indeed, this extensive effort culminated in the experimental observation of the QAH effect in Cr-doped $(Bi,Sb)_2Te_3$ ferromagnetic topological insulator films in 2013 by Xue and coworkers [4]. Nevertheless, the QAH phase appeared at extremely low temperatures (less than 30 mK) due to the small band gap, weak magnetic coupling and low carrier mobility. These factors hinder