

Special Issue

Lessons Learned from Coordinating Research on the North Atlantic (CORONA)¹

When the Bering Strait opened for the first time five million years ago, it set in motion a grand natural experiment in the North Atlantic. Like most biotic interchanges, this one was asymmetric, with most species moving from the Pacific to the Atlantic. The opening of the Bering Strait happened before there was a polar ice cap. In the absence of an icy barrier, temperate species could move freely between oceans. Depending on the habitat, invaders from the Pacific represent between 50% and 80% of the marine biotas in the present-day North Atlantic. Furthermore, North Pacific invaders make up the majority of species with trans-Atlantic distributions; Atlantic endemics are much less likely to be found on both coasts of the North Atlantic.

This grand natural experiment placed thousands of species that evolved in the North Pacific into novel environments on both coasts of the North Atlantic. This experiment established the potential not only for comparing the ecological performance of closely related species between the North Pacific and North Atlantic, but also for comparing species across the North Atlantic. Yet, with the important exception of fisheries research, American and European scientists rarely crossed the Atlantic to see how their study species fared in the drastically different environments on the opposite shore.

Not being ones to allow a grand natural experiment to go to waste, we persuaded the NSF to devote one of their innovative Research Coordination Networks to a basin-wide, multi-disciplinary study of the North Atlantic (NSF DEB-0130275). Between 2002 and 2006, the CORONA group met in Maine, Iceland, the United Kingdom, France, and Portugal. More than 150 scientists attended at least one CORONA meeting, and 25 attended four of the five meetings (see verbatim minutes of these meetings in the Appendix). These included phycologists, ichthyologists, and invertebrate biologists, and encompassed the disciplines of ecology, phylogeography, evolutionary genetics, paleontology, and biological oceanography.

The first goal of the CORONA network was to change the nature of North Atlantic empirical research by expanding our vision both geographically (through international collaboration) and scientifically (through cross-disciplinary collaboration). Both kinds of collaboration are facilitated by the simple act of meeting people who would not usually attend the same scientific meetings. A biogeographic focus provided a particularly productive environment for multidisciplinary collaboration. Because all participants know and love the same geographical area, this shared knowledge can act as a Rosetta Stone to help scientists better communicate their vision and ideas.

While our first goal was to expand the amount and scope of data being collected, the second goal of the CORONA network was to summarize and interpret our collective knowledge of existing data. The eight papers in this Special Issue of *Ecology* represent our attempt to achieve this second goal. This volume represents the culmination of five years of meetings, with the last two meetings devoted entirely to synthetic working groups.

The resulting papers include three comprehensive, synthetic reviews of the literature on ecology (Jenkins et al.), paleo-climate change (Greene et al.), and evolutionary genetics (Schmidt et al.). Five quantitative analyses test hypotheses on body size through time (Vermeij et al.), paleo-diversity (Yasuhara and Cronin), contemporary diversity (Witman et al.), oceanography and settlement (Broitman et al.), and phylogeography (Maggs et al.). The papers are evenly balanced between those emphasizing a historical perspective encompassing the past several million years (Greene et al., Maggs et al., Vermeij et al., and Yasuhara and Cronin), and those focusing on contemporary patterns (Broitman et al., Jenkins et al., Schmidt et al., and Witman et al.).

The papers in this volume take advantage of two comparative frameworks available in the North Atlantic: a geographic framework comparing the North American and European Atlantic coasts; and a temporal framework seeking generality through time. Jenkins et al. begin our volume by introducing a geographic comparative framework. The American Atlantic has predominantly linear coastlines and soft-bottom habitat. In contrast, the European coastline is more convoluted at several geographical scales, with mostly rocky shores. Jenkins et al. comprehensively classify and review two generations of benthic experimental studies. They show that the same ecological processes have been

¹ Reprints of this 122-page Special Issue are available for \$20.00 each. Prepayment is required. Order reprints from the Ecological Society of America, Attention: Reprint Department, 1990 M Street, N.W., Suite 700, Washington, DC 20036.

experimentally demonstrated on both sides of the North Atlantic, but their relative importance varies with geography and with substratum type. The relative importance of these ecological processes is due in part to trans-Atlantic differences in the presence and importance of key taxa such as bioturbators and grazing herbivores.

The second paper, by Greene et al., introduces a temporal framework for the Northern Hemisphere with an engaging review of the past 65 million years of climate and oceanography. The goal of the paper is to draw insights about the potential ecological impacts of contemporary climate change by reviewing major climatic transitions in the past. Greene et al. conclude with a review of recent evidence for climate-associated ecosystem regime shifts and biogeographic range shifts in the North Atlantic, including new trans-Arctic invasions of certain Pacific planktonic species.

Vermeij et al. take advantage of both the geographic and temporal comparative frameworks by tracing the history of 18 distinct guilds of marine invertebrates since the Miocene. They find that contemporary trans-Atlantic differences in maximum body size are remarkably constant over time, with larger maximum sizes in hard-bottom guilds in Europe, and in soft-bottom guilds in America. They suggest that these size differences reflect either habitat-specific differences in productivity or evolutionary processes such as predator-prey escalation.

Yasuhara and Cronin also use a temporal framework to explore the correlates of biodiversity. By reviewing the literature on fossil-rich assemblages of North Atlantic deep-water ostracodes and high diversity, they show a positive correlation between warm temperatures and high species diversity. The major exception to this pattern was at high-latitude sites in the past 200 thousand years due to dramatic decreases in productivity caused by millennial-scale ice-rafting events.

Witman et al. use a geographic framework to explore the relationship between diversity and productivity for invertebrates across three very different geographical areas: Arctic soft-bottom communities, the brackish St. Lawrence Seaway, and subtidal rock walls across the North Atlantic. This novel synthesis, using quantitative measures of surface productivity, found both negative and hump-shaped relationships between species diversity and productivity across local, regional, and continental scales.

Broitman et al. use a much shorter temporal scale to apply a novel approach to investigating the influence of atmospheric cycles on the settlement of marine invertebrates. Though they were hampered by the absence of appropriate long-term studies outside of Britain, they find support for two different mechanisms by which the North Atlantic Oscillation (NAO) might influence invertebrate recruitment. They suggest that the NAO might affect recruits both by atmospheric temperatures experienced by settling recruits and by more long-term changes in ocean circulation patterns.

Schmidt et al. review the widespread application of evolutionary genetic methods to studies across the North Atlantic. They make an especially strong case for the geographical framework when they argue that the North Atlantic is particularly well suited for comparative studies. They show how similar clines in selection pressure can be replicated many times. Just as large-scale latitudinal clines are replicated in both Europe and North America, micro-scale clines through the intertidal zone are replicated everywhere there is a significant tide.

Finally, Maggs et al. also review the use of genetic methods in a geographical context, but they take an explicitly historical approach when considering the evidence for glacial refugia in marine animals and algae. They use a series of case studies to explore genetic signatures that have been used to infer the existence of populations that may have survived in small refugia. In particular, they explain how, in some cases, such refugia can produce high genetic diversity in northern areas, in contrast to the widespread expectation that northern areas should have lower genetic diversity.

All authors of the papers in this Special Issue are keenly aware of the changing environment. While phylogeographic studies may help predict which species are more likely to cross the Arctic as the ice cap melts, a synthesis between oceanography and ecology is needed to predict the influence of climate change on distribution and abundance of populations. Each paper looks to the future and suggests specific research programs that will be needed to answer the questions they raise.

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APPENDIX

Additional information on CORONA, including verbatim minutes of the meetings (*Ecological Archives* E089-185-A1).