

Station ALOHA: A Gathering Place for Discovery, Education, and Scientific Collaboration

David M. Karl , and Matthew J. Church

Editor's Note: This is the opening editorial for a virtual issue of research conducted at Station ALOHA and published in Limnology & Oceanography over the past three decades. The complete virtual issue may be accessed at [https://aslopubs.onlinelibrary.wiley.com/doi/toc/10.1002/\(ISSN\)1939-5590.ALOHA30](https://aslopubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1939-5590.ALOHA30)

On 30 October 1988, a team of scientists from the University of Hawaii established Station ALOHA (22°45'N, 158°W; Fig. 1) as an open ocean observatory for physical, biogeochemical, and ecological investigations. ALOHA is an acronym for *A Long-term Oligotrophic Habitat Assessment*, the stated mission of the National Science Foundation-supported Hawaii Ocean Time-series (HOT) program. On approximately monthly intervals since then, scientists, engineers, students, and technicians from around the world have embarked on more than 300 expeditions to observe and record both natural and human-induced variations in ecosystem structure and function at this remote open ocean location. Such studies have identified key processes and patterns associated with biogeochemical cycles of carbon and associated bioelements, including those controlled by time-variable plankton

biology, air–sea interactions, and vertical and horizontal fluxes of nutrients. Between 2006 and 2016, the National Science Foundation funded the Center for Microbial Oceanography: Research and Education (C-MORE) as a Science and Technology Center of excellence, and in 2014 the Simons Foundation established a decade-long international program dubbed SCOPE, the Simons Collaboration on Ocean Processes and Ecology. Both C-MORE and SCOPE were created on the intellectual foundation that was built by the HOT program, and both have complemented the long-term time series with more comprehensive investigations of microbial processes, biogeochemistry, and ecosystem modeling.

This virtual issue presents some of the key scientific discoveries made at Station ALOHA and published in *Limnology and Oceanography* over the past three decades. Included are papers highlighting spatial and temporal variability in the North Pacific Subtropical Gyre (NPSG) ecosystem from surface waters to the deep sea, the development of novel methods and instrumentation for investigations of biogeochemistry and ecology, and selected data synthesis and modeling efforts. As detailed below, these

contributions, along with many others that have appeared in a broad range of scientific journals, challenge existing paradigms and continue to transform our understanding of coupled physical–chemical–biological interactions and the impacts of climate change on marine ecosystems. In recognition of these “historic and visionary accomplishments,” the American Society for Microbiology recently designated Station ALOHA as a Milestones in Microbiology Site, one of only 15 institutions, scientists, or locations where significant contributions toward advancing the science of microbiology have been achieved (<https://www.asm.org/index.php/about-microbiology/history-4>).

The HOT program emerged from international planning efforts to systematically study the global carbon cycle, both on land and at sea. It was argued that a comprehensive understanding would be necessary to address contemporary scientific and societal issues related to atmospheric accumulation of greenhouse gases and their cumulative impacts on ecosystems, species biodiversity, and biogeochemical cycles. Detailed *in situ* studies of key ecosystems would need to be interdisciplinary in scope to understand the inextricable linkages between and among

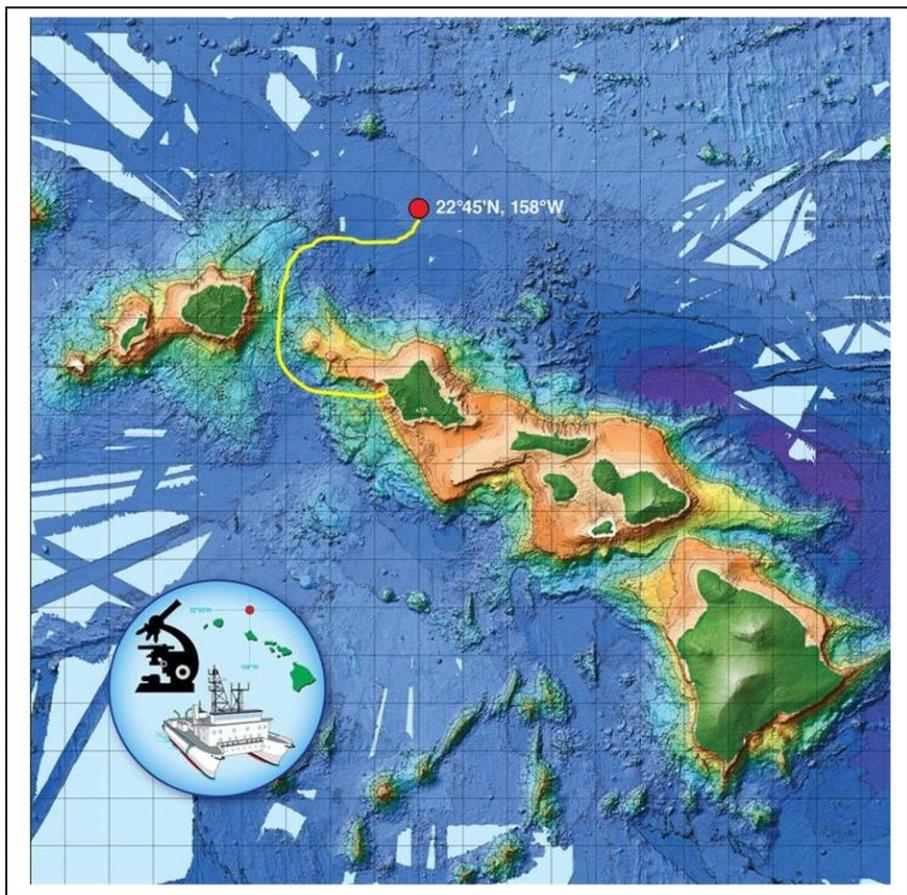


FIG. 1. Map of the Hawaiian Islands showing the location of Station ALOHA (red circle) at 22°45'N, 158°W and the cable route (yellow) for the ALOHA Cabled Observatory. Bathymetric synthesis from Hawaii Mapping Research Group.

physics, chemistry, and biology in each ecosystem. Moreover, such studies would need to be designed in such a way as to enable deconvolution of natural variability from human-induced changes. In response to the growing awareness of the ocean's role in climate, and especially the role of planktonic organisms in long-term carbon sequestration via the so-called biological pump, the International Geosphere-Biosphere Programme (IGBP): A Study of Global Change was established in 1986. A key component of IGBP, the Joint Global Ocean Flux Study (JGOFS) program, was established 1 yr later. JGOFS grew out of an earlier U.S.-based effort, GOFS, which was established in 1984 at a National Research Council-sponsored workshop. The GOFS report concluded: "The physical, chemical, and biological processes governing the production and fate of biogenic materials in the sea need to be understood well enough to predict their influences on, and responses to, global-scale

perturbations, whether natural or anthropogenic, since these perturbations can have a significant impact on human populations." The report recommended that "a long-term multidisciplinary study of the flux of material through the global ocean environment is needed." The rapid pace of anthropogenic change impacting Earth's ecosystems highlighted the urgency and importance of creating and sustaining high quality time-series measurements of the ocean-climate system. In 1988, under the auspices of GOFS and the World Ocean Circulation Experiment program, the National Science Foundation supported the establishment of HOT to provide information on seasonal to interannual scale variability in ocean physics, biogeochemistry, and ecosystem processes in one of Earth's largest habitats, the NPSG.

Located approximately 100 km north of Oahu, Hawaii, Station ALOHA has become a global ocean reference point for tracking oceanic and ecosystem dynamics,

and it has already had a major impact on how we study, interpret, and model biogeochemical processes in oligotrophic ecosystems. Many of the general characteristics of the NPSG habitat were known prior to the establishment of Station ALOHA, but other features were either poorly understood or not yet discovered. For example, the three major groups of microorganisms that are numerically dominant members of the NPSG ecosystem (i.e., *Prochlorococcus* spp., the SAR 11 clade of *Alphaproteobacteria*, and planktonic archaea) were all discovered after the establishment of Station ALOHA in 1988. Furthermore, the origins of the marine -omics revolution postdate the creation of HOT. From the beginning, HOT was conceived as a research vessel-based sampling and observation program. Over the years, additional remote-sensing assets including satellites, floats, moorings, autonomous underwater vehicles, bottom-moored sediment traps, and a deep-sea cabled

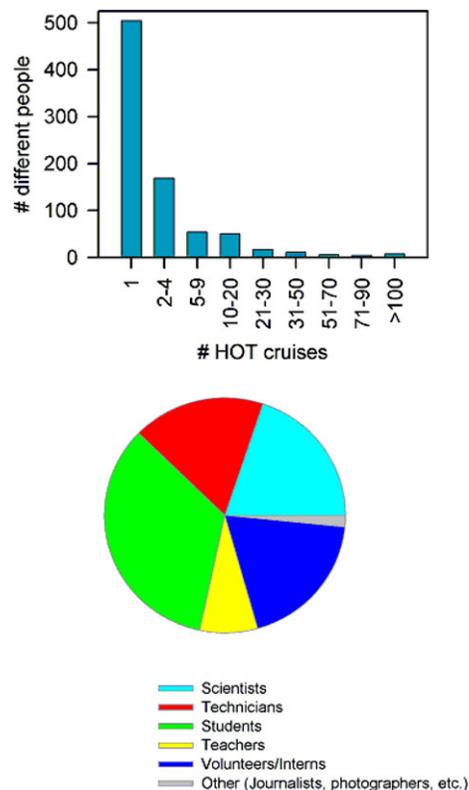


FIG. 2. HOTA program cruise participants from 1988 to 2018. (Top) Frequency histogram of participation in the first 300 HOTA cruises. Total number of individual participants who have sailed on HOTA cruises is 827. (Bottom) Pie chart showing the breakdown by occupation showing the large proportion of students and trainees.

observatory have enhanced the value of the core measurement program. The resulting data, which are all publicly available (http://hahana.soest.hawaii.edu/hot/hot_jgofs.html), have already helped to define major patterns and time-varying dynamics associated with ocean hydrography, biogeochemistry, and controls on primary production and export. The sustained measurements at Station ALOHA provide some of the only multidecadal ocean observations from which we can gauge future changes to the ocean.

Any contemporary time-series observation program, including HOT, regardless of when it began or how long it has been active, captures only a snapshot of the complex time-space continuum of natural environmental variability along with a superimposition of human impacts. It has been demonstrated that for systems like the NPSG, where the signal-to-noise ratio is low, unambiguous detection of climate change impacts on ecosystem structure and function may require 40 yrs, or more, of observation. Furthermore, human-induced climate change is predicted to alter marine ecosystems in a complex manner due to multiple synergistic and antagonistic stressors acting on a variety of time and space scales. Some ecological processes will have thresholds or tipping points beyond which they may become vulnerable to collapse. These sobering realities present a monumental challenge but, at the same time, incentivize

and motivate the scientists involved in HOT to sustain this critical observation program.

The papers in this virtual issue are presented chronologically in broad categories that comprise the major topics under investigation. However, the true value of programs like HOT, C-MORE, and SCOPE is derived from the transdisciplinary collaborative research that has been encouraged since the beginning of the program. Station ALOHA has become a proving ground for hypothesis testing and ecosystem experimentation, and an oceanic university for training the next generation of leaders. Long-term field programs like HOT require dedicated efforts of a large number of skilled technical staff, students, post-docs, and administrators (Fig. 2). These are the unsung ALOHA heroes. Many of the staff members have a decade, or more, of service to the HOT program, and eight individuals have participated in 100+ HOT expeditions. Blake Watkins, a marine engineer in HOT, just completed 147 cruises, including a decade-long period of 100 consecutive cruises (HOT-206 to HOT-305). Four members of the team (Dan Sadler, Fernando Santiago-Mandujano, Lance Fujieki, and Jeffrey Snyder) have surpassed 200 cruises during their HOT careers. These are remarkable achievements by any measure and a clear indication of their dedication to the HOT mission.

With each additional expedition to Station ALOHA, the time series becomes more

valuable for the detection and interpretation of ecosystem variability. The observations and experimentation conducted at Station ALOHA, including C-MORE and SCOPE, have contributed to the growing base of knowledge in ways that could not have been predicted when the program began in 1988. Ultimately, the creation and dissemination of scientific knowledge must be a primary motivation if a long-term time-series program is to remain vibrant and relevant. To date, more than 700 peer-reviewed journal articles and invited book chapters have resulted from research conducted at Station ALOHA. HOTEL, the HOT Electronic Library, is available at: hahana.soest.hawaii.edu to supplement this current selection of papers that appeared in *Limnology and Oceanography*. The assessment of NPSG ecosystem dynamics is still a work in progress. Funding to continue the HOT program through July 2023 has recently been received. This will help to sustain the current pace of new discovery and further contribute to our understanding of the sea around us.

David M. Karl, Department of Oceanography, University of Hawai'i at Manoa, Honolulu, HI; dkarl@hawaii.edu

Matthew J. Church, Flathead Lake Biological Station, University of Montana, Missoula, MT