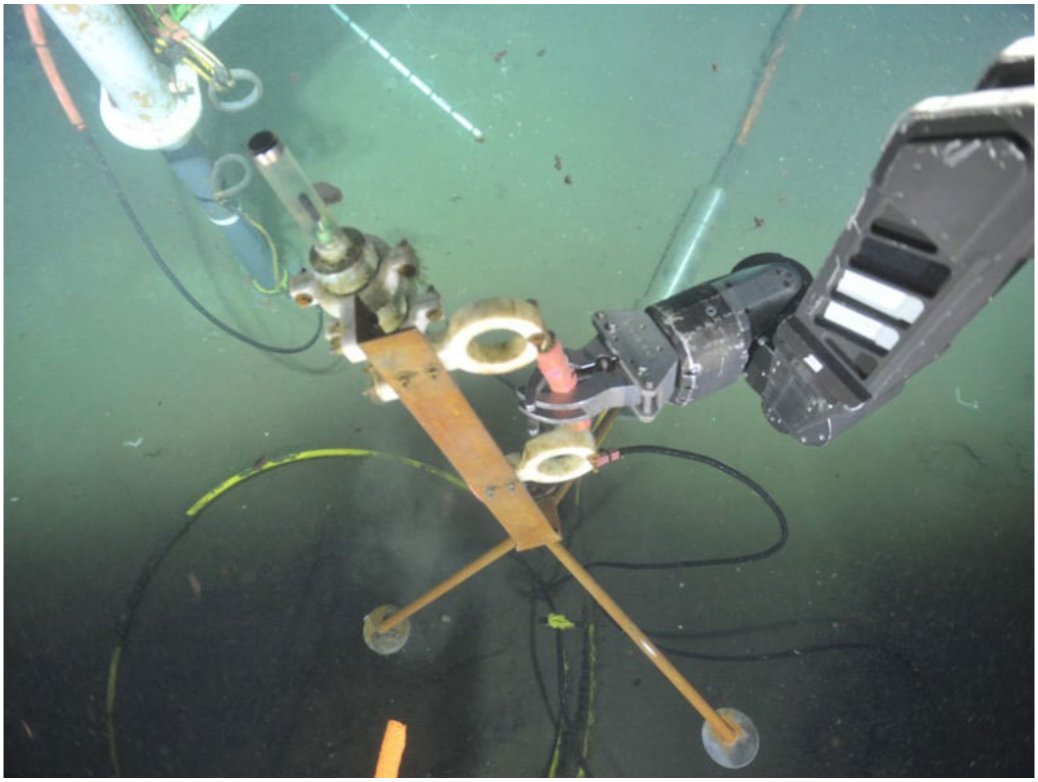
https://eos.org/science-updates/measuring-ambient-ocean-sound-during-the-covid-19-pandemic

Measuring Ambient Ocean Sound During the COVID-19 Pandemic

An expanded nonmilitary hydrophone network provides new opportunities to understand the variability and trends of ocean sound and the effects of sound on marine organisms.



A robotic arm (at right) retrieves a hydrophone (center), an underwater microphone that records natural and human-produced sounds in the ocean. Credit: Ocean Networks Canada, CC BY-NC-SA 2.0

By Peter L. Tyack, Jennifer Miksis-Olds, Jesse Ausubel, and Edward R. Urban Jr. 4 March 2021

Extreme events—volcanic eruptions, tsunamis, nuclear weapons tests, and the like—can cause extreme harm. However, such events can also serve as de facto experiments that help scientists understand and predict the effects of human activities on natural systems [*Bates et al.*, 2020; *Rutz et al.*, 2020]. In one striking example, contraction of the world economy during the COVID-19 pandemic has allowed scientists to measure ambient sound levels in the global ocean during a time of major decreases in noise from shipping and many other marine activities that is unprecedented in the recent past.

Sound propagates farther than any other signal in the ocean, making it the best way to communicate and orient underwater. Since World War I, navies around the world have monitored ocean sound to locate submarines and mines and for other national security purposes. Underwater listening technology has also supported many other discoveries, including how whales use sound to communicate across the ocean.

Despite all we have learned about ocean sound, however, the effects of human-generated ocean sounds on marine animals that use sound to navigate and communicate remain poorly understood. An important way we can improve our understanding of human effects is to quantify variability and change in ambient, or background, ocean sound over time, which makes it possible to characterize marine "soundscapes."

Characterizing the risks of underwater sound for marine life requires understanding what sound levels cause the effects.Characterizing the risks of underwater sound for marine life requires understanding what sound levels cause harmful effects and where in the ocean vulnerable animals may be exposed to sound exceeding these levels. But the sporadic deployment of hydrophones globally and the lack of public access to military hydrophone data have hindered scientific efforts to pursue such quantifications. (Peer-reviewed journals increasingly require open access to data on which submitted papers are based.)

Concerns about national security have kept much acoustic data, some decades old, classified or difficult to access. One notable exception involves data from the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), the organization that monitors compliance with the Comprehensive Nuclear-Test-Ban Treaty (CTBT), which opened for signature in 1996 and bans nuclear explosions on and below Earth's surface, in the atmosphere, and underwater.

CTBTO uses seismic, infrasound, radionuclide, and hydroacoustic stations to monitor for nuclear explosions. Of the 11 CTBTO hydroacoustic stations that monitor the global ocean, five use seismometers to pick up waterborne signals coupled to Earth's crust. The other six are cabled stations that use underwater hydrophones deployed near the deep sound channel, a horizontal subsurface water layer that acts as a waveguide for sound. The Virtual Data Exploitation Centre (vDEC) platform is designed to provide access to CTBT data to scientists and researchers around the globe.

However, other than the CTBTO stations and a small number of other cabled listening stations, most nonmilitary hydrophones are deployed for only a few months or years for specific, stakeholder-driven research or monitoring purposes. As a result of this shortage of data, there is no continuous and long-term record of ambient ocean sound equivalent to, say, the famous Keeling curve, which has tracked the overall rise and seasonal fluctuations of atmospheric carbon dioxide concentrations since 1957 [*Keeling et al.*, 1976].

In 2011, an international group of experts concerned with ocean sound and its effects on marine life began developing the International Quiet Ocean Experiment (IQOE), which was formally launched in 2015 with publication of the *International Quiet Ocean Experiment Science Plan*. A goal of IQOE is to create time series of measurements of ambient sound in the ocean in many locations to reveal variability and changes in intensity and other properties of sound at a range of frequencies.

IQOE has encouraged increased deployment of civilian hydrophones worldwide. And indeed, the number of hydrophones operating in North America [e.g., *Haver et al.*, 2018], Europe, and other locations for both research and operational purposes has increased dramatically, likely thanks in part to IQOE. With these increased resources, IQOE and the ocean sound research community will be able to shed needed light on humans' influences on marine life and ecosystems, as well as on how the COVID-19 pandemic is affecting the ocean.

Ocean Sound and the COVID-19 Pandemic

Most studies of the effects of ocean noise from natural and human sources broadcast acoustic signals and monitor for any resulting short-term effects on marine life, or they work backward from observed effects to determine sound sources. IQOE is based upon the recognition that if added noise already harms animals and affects marine ecosystems negatively, then measuring effects of reducing noise should be a key goal of marine bioacoustics.

Travel restrictions and economic slowdowns occurring globally in response to the COVID-19 pandemic put the brakes on much human activity in the ocean.Beginning in January 2020, travel restrictions and economic slowdowns occurring globally in response to the COVID-19 pandemic—and intensified by an oil price war—put the brakes on much human activity in the ocean. Drastic decreases were seen in shipping, tourism and recreation, fishing and aquaculture, energy exploration and extraction, naval and coast guard exercises, offshore construction, and port and channel dredging.

The global pandemic has thus created a chance for scientists to determine how a sudden decrease in human activities—already attested to by atmospheric and terrestrial measures—and the subsequent slow recovery of the global economy affect sound levels in the ocean.

Other unintentional historical events provide analogies to the current drop in human activities on and in the world's oceans. The start (1945) and stop (1980) of aboveground nuclear testing provided traces of carbon-14 and tritium, whose movements and decay have provided major insights into ocean physics, chemistry, and biology. And after the terrorist attacks in New York City and Arlington, Va., on 11 September 2001, the cancellation of hundreds of civilian airline flights allowed scientists to study the effects of jet contrails (or their absence) on weather patterns.

Listening to Quieter Oceans

A previous opportunity to study the effects of reduced ocean noise arose from the slowdown of shipping following the events of 11 September 2001. For example, a group of biologists studied the levels of stress hormones in endangered North Atlantic right whales in the Bay of Fundy. They found that during the 4 years after 2001, stress hormone levels increased in mid-September as the whales prepared to migrate from their northern feeding and mating area to warmer southern waters where they calve. However, immediately after 11 September 2001, ocean noise levels from shipping decreased, and levels of stress hormone dropped [*Rolland et al.*, 2012]. This study suggests that living in an industrialized ocean chronically stresses these whales and that the reduction in noise reduced their stress.

Fortuitously for the ocean research community, a large number of nonmilitary hydrophones were already deployed worldwide before the pandemic, so there is a significant opportunity to study its ramifications on ocean sound globally. IQOE is working with the ocean observing community to identify a global network of civilian-operated, passive acoustic hydrophones (i.e., those that record ambient sounds rather than generating sounds of their own) useful for this purpose. This network could also serve more broadly as a prototype global hydrophone network for scientific and monitoring purposes.

As of 8 February 2021, we had identified 231 hydrophones that could contribute to a global analysis of the effects of the pandemic on ocean sound (Figure 1). Most identified so far are located in waters of the United States and Canada, but increasing numbers are being added elsewhere, particularly in

European waters. Meanwhile, more acoustic instrumentation and measurements are clearly needed across the Southern Hemisphere.

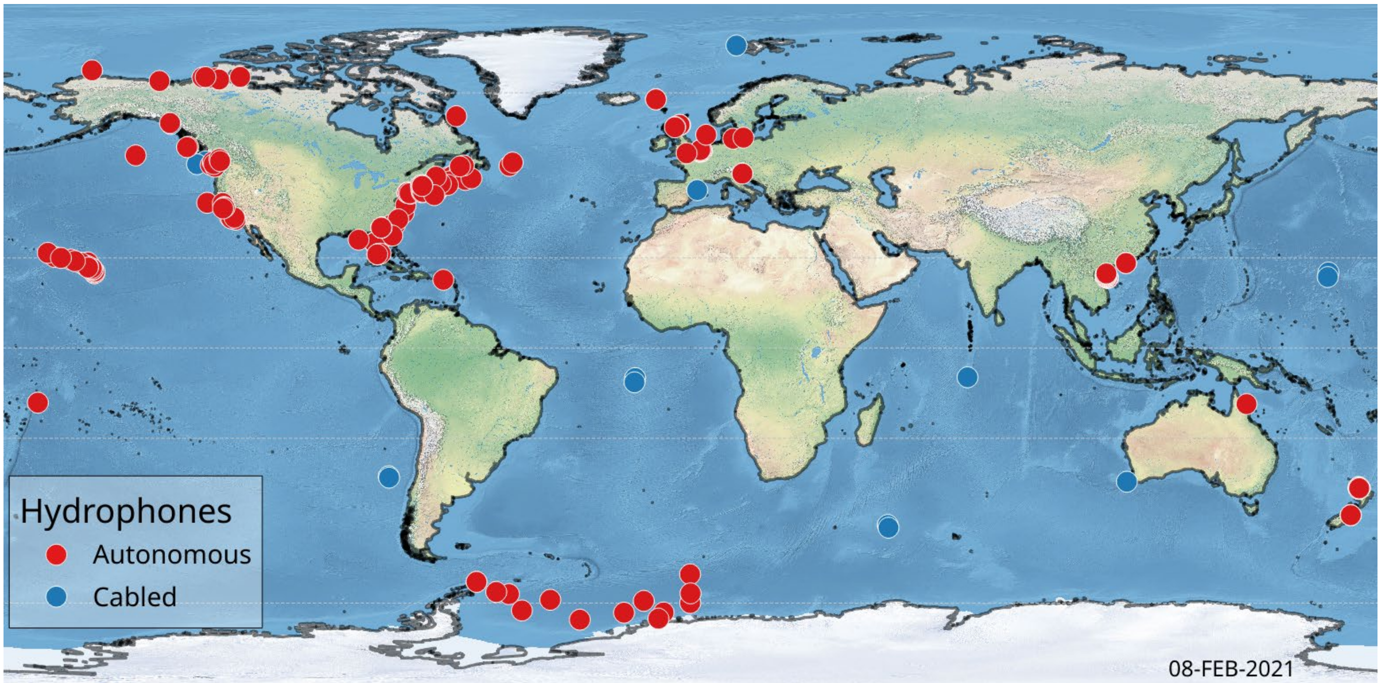


Fig. 1. Locations of civilian hydrophones potentially useful to study effects of the COVID-19 pandemic on ocean sound and other acoustic characteristics of the ocean are shown here, as of 8 February 2021.

It is important that acoustic monitoring by many existing hydrophones continue at least through 2021 to make sure researchers can observe a complete return to baseline conditions if the pandemic subsides by then (Figure 2). Such consistency is a challenge, however, because the pandemic has interrupted the placement and servicing of hydrophones and other parts of ocean observing systems in most of the world.

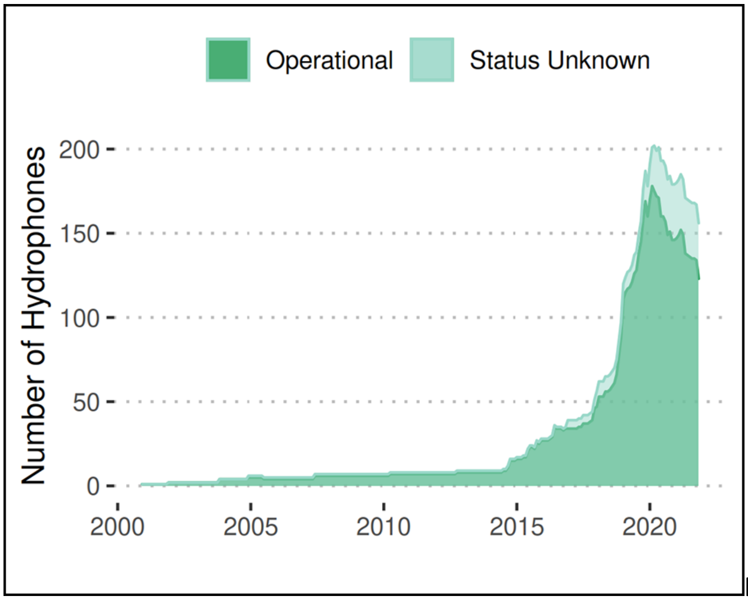


Fig. 2. Trends in the number of nonmilitary hydrophones deployed over the past 20 years as of 8 February 2021. The dark green area ("operational") represents hydrophone installations that are operational and are planned to be continued into the indefinite future, depending on continued funding by institutions and governments. Additional hydrophone installations whose end dates could not be verified but are currently operational are shown in lighter green ("status unknown"). Temporary installations before 2019 are not well represented, as this survey was mainly concerned with effects of the onset of COVID-19. The World Health Organization declared COVID-19 a pandemic on 11 March 2020.

Because most hydrophone installations are autonomous recorders that are not equipped for telemetry (Figure 1), most hydrophone data are not available in real time; further, the pandemic has delayed the recovery of some data. The schedule of data recovery dictated by pandemic-related disruptions will affect the timing of the global analysis of hydrophone data for assessing large-scale impacts. However, researchers have already released some preliminary real-time results detailing regional ocean quieting near Vancouver, Canada [*Thomson and Barclay*, 2020]. Extending these observations to include measurements on a global scale should be exciting.

The existing hydrophone network covers coastal areas, which are likely those most influenced by local changes in human activity, and it also includes deep-ocean stations that can measure effects of low-frequency sound sources over large areas. The more areas that can be sampled, the more accurate our view of the global effect of COVID-19 on ocean sound will be. As such, IQOE continues to welcome expansion of the global passive acoustic network.

Requirements for a Global Data Set

Achieving a global data set that will help discern effects of the pandemic on ocean sound and its consequences for marine life will require stakeholders, including hydrophone operators, ocean acoustics and bioacoustics scientists, national funding agencies, and others, to take several actions:

1. Gather metadata and deployment information about the instruments collecting acoustic data, such as the geographic location, deployment depth, and technical characteristics of the hydrophones, and about how they were calibrated. Use these data along with modeling of how

sound propagates at the different sites to identify the importance of each station to a global time series. (For example, some stations fill geographic gaps in the observing network, whereas other more closely spaced stations help identify sound source locations more precisely.) This effort is already underway.

2. Process data using a consistent and comparable method. The IQOE community has been working for the past several years with data owners and other stakeholders on guidelines for measuring, processing, and reporting ocean sound levels, described in its "Guidelines for Observation of Ocean Sound." This document recommends key consensus parameters for ocean sound level measurements that will enable comparison of sound levels among hydrophones made by different manufacturers. The IQOE's global sound analysis will need to consider whether the output from each hydrophone meets quality standards. To facilitate standardized data processing, the Richard Lounsbery Foundation is supporting a software project to produce consistent outputs from passive acoustic recordings based on the IQOE guidelines. This software, called Ocean Sound Software for Making Ambient Noise Trends Accessible (MANTA), will be freely available by the end of March 2021.

3. Scientists over the past decade have developed powerful methods to estimate the distribution and abundance of vocalizing animals using passive acoustic monitoring.Encourage hydrophone operators participating in IQOE to process their raw data with the MANTA software and to contribute outputs to the global COVID-19 sound analysis and the resulting published paper, which will be coauthored by all data contributors. Presumably, hydrophone operators will initially process their raw data using their own techniques and may publish their results independently. But they can then contribute MANTA outputs to community products.

4. Use the hydrophone data to monitor effects on the distribution and behavior of vocalizing animals. Scientists over the past decade have developed powerful methods to estimate the distribution and abundance of vocalizing animals using passive acoustic monitoring [*Marques et al.*, 2013]. These methods are well suited to studying long-term effects of changes in ocean sound.

5. Create a sustainable data repository to which hydrophone operators will be encouraged to submit processed data, perhaps along the lines of the network of Argo floats, which are continually recruited and whose metadata are constantly curated. The Alfred Wegener Institute in Bremerhaven, Germany, has established the Ocean Portal to Underwater Soundscapes (OPUS) for access to compilations of MANTA outputs for the community to analyze.

A Broader Scope for Ocean Acoustics

Beyond analyzing effects of pandemic-related decreases in human activity on ocean sound and potential follow-on effects on ocean ecosystems, the fledgling hydrophone network will continue contributing to the Global Ocean Observing System (GOOS). This system is a worldwide collaboration of observing assets, including Argo floats, sea level monitoring stations, fixed and drifting buoys, and others.

GOOS leadership embraced a strong vision for increasing acoustic measurements at the OceanObs'19 conference [*Howe et al.*, 2019]. The organization selects ocean parameters, designated as Essential Ocean Variables (EOVs), on which to focus based upon feasibility and their scientific and societal relevance. The GOOS Biology and Ecology Panel approved an Ocean Sound EOV and assigned IQOE responsibility for leading the EOV effort. As soon as it is feasible on the basis of COVID-19 health and safety concerns, IQOE will conduct a workshop to develop an implementation plan for the Ocean Sound EOV; participants in this workshop could form a nucleus of people committed to fulfilling the plan.

Timely maturation of a global marine passive acoustic network is helping to meet the GOOS goal of monitoring ocean sound. Such capabilities will allow researchers to further analyze acoustic data to shed light on the distribution of ocean sound and its effects in Anthropocene seas [*Duarte et al.*, 2021]. These efforts will go a long way toward improving our limited understanding of the effects that humans have on marine life and ecosystems. Let's learn from the COVID-19 pause to help achieve safer operations for shipping industries, offshore energy operators, navies, and other users of the ocean.

Acknowledgments

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