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ARTICLE

The Silence of Global Oceans: Acoustics Impact of the Covid-19 Lockdown

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Low-frequency noise from marine shipping is an underwater acoustic pollutant in oceans. The noise spectrum overlaps with frequencies marine mammals use to communicate and navigate, leading to stress and increasing collision with ships. This research established a model to measure the contribution of anthropogenic activities to underwater noise levels. The COVID-19 lockdown led to a global decline in commercial and cruise shipping. The model quantified the reduction in noise levels before and during the lockdown in the Arctic, Atlantic, Pacific Oceans, and Mediterranean Sea. Underwater, ocean sound peaks between 10 – 100 Hz and is dominated by noise from shipping traffic. Hydrophone (underwater microphone) data from seven ocean observatories were analyzed at 1 Hz spectral and 1-minute temporal resolution. Power spectral densities were calculated, aggregated into monthly long-term spectral averages, and noise levels in the 63 Hz third-octave band compared to previous years. The analysis revealed that global oceans quietened by an average of 4.5 dB, or the peak sound intensity decreased 2.8 times during the lockdown period. The maximum decrease was at locations close to major shipping channels and cruise tourism destinations. The findings were validated by comparing shipping traffic using the satellite-based Automated Identification System (AIS). The study proved that strategic "anthropauses" could reduce underwater noise levels and give marine mammals a chance to reverse the decline in their population. An open-source interactive web application MonitorMyOcean.com was created to provide updated anthropogenic noise levels in global oceans. Policymakers can determine if measures such as shifting shipping channels or moratoriums on new shipping routes are leading to "Quieter Oceans." The App has been endorsed by the Intergovernmental Oceanographic Commission (IOC) of UNESCO as a UN Ocean Decade Activity.

INTRODUCTION

Low-frequency sound from maritime shipping is a major source of ambient underwater noise in oceans and a threat to marine life. Annual increases in global trade, 80% of which occurs through ocean tankers and container ships, mean that underwater anthropogenic noise levels are increasing. (United Nations Conference on Trade and Development ([UNCTAD], 2021). As seasonal ice disappears because of climate change and new shipping routes open in the Arctic, ambient sound levels are bound to increase.

Anthropogenic noise is an acoustic pollutant. In the darkness of the oceans, marine life has evolved to use acoustic cues to communicate, migrate, forage, and reproduce. Unfortunately, low-frequency sounds (20 Hz - 200 Hz) radiated by propellers and machinery of over 60,000 commercial vessels traversing the oceans overlap with frequency bands used by marine life. (Figure 1). Elevated low-frequency underwater noise levels near busy shipping routes and ports have the potential to interfere significantly with whale calls ('acoustic masking') (Rolland et al., 2012). It can damage their hearing leading to stranding, inability to hunt, and collision with ships.

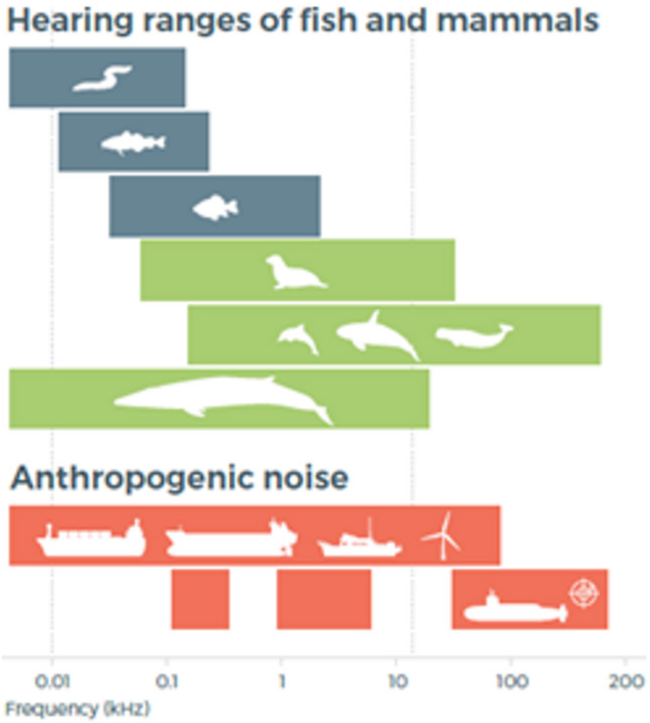


Figure 1: Overlapping of frequency bands of shipping noise with those used by marine life for communication. Source: Ocean.org

RESEARCH RATIONALE

The onset of the COVID-19 pandemic in early 2020 brought an unexpected global 'anthropause.' The economic slowdown and travel restrictions meant nearly 44% of the global and 77.5% of national ocean jurisdictions showed a decrease in shipping traffic density during April 2020 (March et al., 2021). According to the United Nations Maritime Transport 2021 Report, the economic slowdown and travel restrictions led to a 17% dip in commercial shipping in the second quarter of 2020 and an 80% drop in ocean cruise liners traffic compared to 2019. The ocean cruise season was canceled in 2020 by most counties. It was a rare research opportunity to create a time series quantifying the relationship between changes in anthropogenic activities and ambient noise levels in oceans.

RESEARCH GOALS

1. Create a quantitative model to measure anthropogenic noise levels in oceans.
2. Use the model to measure the impact of COVID-19 restrictions on ambient noise levels in global oceans.

As new marine economic activities, such as deep-sea mining, likely get approved, and year-round new shipping routes open in the Arctic due to the melting of sea ice, sound levels in oceans are bound to increase. The research will provide an effective way to track changes in anthropogenic noise levels in global oceans and mitigate the adverse impacts of the economic exploitation of oceans and climate change on marine biodiversity.

As the issue of ocean noise cuts across national jurisdictions, it would require regional and international cooperation. Submissions will be made to several UN and intergovernmental agencies, including the International Maritime Organisation (IMO) responsible for international shipping routes and regulations, the Convention on Biodiversity (CBD) for consideration of ocean noise in spatial planning and in the management of marine protected areas (MPAs), and the International Seabed Authority (ISA) to embed environmental regulations related to ocean noise within the "Mining Code" related to deep sea mining. Submissions will also be initiated with policy-making processes in Canada to strengthen its ocean noise strategy.

Figure 2: Selection of hydrophones in global oceans

RESEARCH HYPOTHESIS

The COVID-19 restrictions would have decreased underwater ambient noise levels in lower frequency bands (<1 kHz) associated with anthropogenic activities in early 2020 compared to previous years. The decrease would have varied across oceanic regions depending on marine activities restricted and the shipping traffic density.

DATA SOURCE

Hydrophones measure noise levels in the oceans. These underwater devices generate an electric signal when subjected to pressure change, allowing them to measure ocean sounds with great precision. I selected eight hydrophones in the Arctic, Atlantic, Pacific Ocean, and the Mediterranean Sea (Figure 2). Each oceanic region was affected by human activities, such as commercial shipping, tourism, passenger ferries, or offshore exploration. I collected wind speed data at hydrophone locations from buoys operated by the National Buoy Data Centre (National Oceanic and Atmospheric Administration, 2021). Over 20 terabytes of data were downloaded and analyzed for this research study.

METHODOLOGY

The classification of primary ambient noise sources in oceans was done using Wenz curves. Wenz curves demonstrate the relationship between sound pressure levels and marine ambient noises at different frequencies. While natural sounds of Earth output most energy from 0 to 10Hz, the ambient noise produced by distant ship traffic is dominant between 10 and 100 Hz, and contributions from ocean winds occur at frequencies between 100 Hz and 25 kHz (Veeriayan & Rajendran, 2021).

A five-step methodology was followed to isolate anthropogenic noise in oceans and observe changes brought by the COVID-19 restrictions.

1. Preprocessing of Data: Downloaded raw audio files from the hydrophones, scaled and indexed the voltage data, and checked for temporal continuity.
2. Nyquist Resampling: Different hydrophones record sounds at different sampling rates. To maintain consistency, I resampled data at 2 kHz. It allowed me to analyze frequencies up to 1000 Hz (Nyquist theorem), in which I was interested.
3. Calculating Power Spectral Densities: I split raw data into 1-minute segments and applied Fast Fourier Transformations (FFT) with a Hann window. It yielded sound pressure levels (power of the acoustic signal as a function of frequency) which were aggregated to create "Monthly long-term spectral averages".
4. Eliminating Wind and Weather Contributions: Daily Ocean conditions at each hydrophone site were categorized using the Beaufort Scale: an empirical measure that relates wind speed to observed conditions at sea. Only measurements with equivalent

natural noise impact were compared so that the resulting differences were due to the variability in the anthropogenic noise (Basan et al., 2021).

5. One-Third Octave Bands Analysis: The frequency bands were divided into 1/3 octave bands for improved resolution. Daily and monthly geometric means, medians, and quantiles of sound pressure levels in 1/3 octave bands centered around 63 Hz were calculated and compared to the previous year to find out changes in underwater noise levels.

Matplotlib, Sci-Kit learn, Plotly, and Dash libraries were used for data analysis, display, and creation of an interactive web application.

RESULTS

I compared underwater noise data for the lockdown period in 2020 with previous or the following year's data depending on the availability to assess changes in noise levels.

Result 1:

The correlation between wind speeds and underwater ambient noise was very weak at lower frequencies

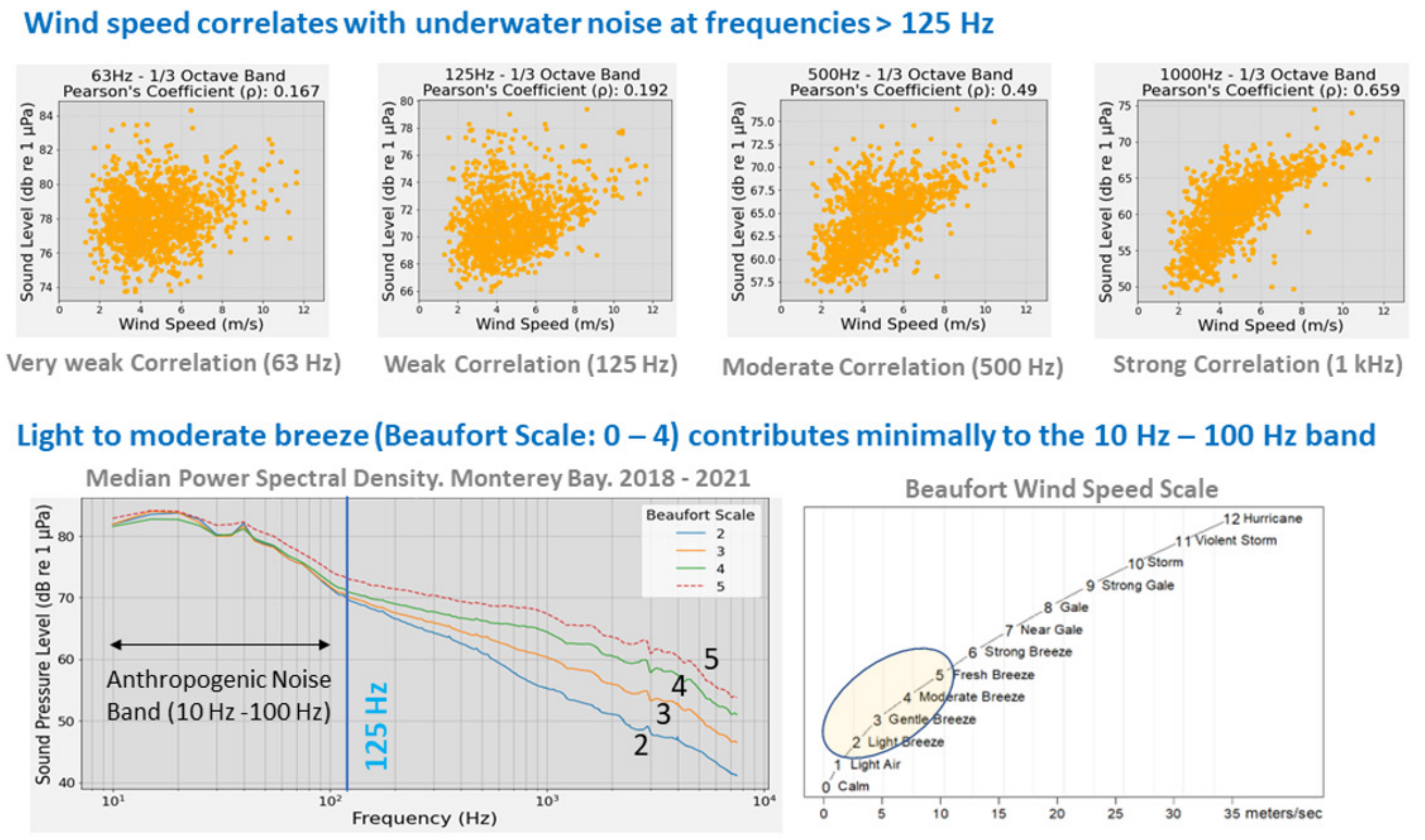
The impact of light to moderate winds, which measured up to 4 on the Beaufort Scale or around 10 m/s, was found to be insignificant at 63Hz third-octave band: 56.2 Hz to 70.8 Hz (Figure 3). This is the band at which shipping outputs the most noise. It meant that contributions of wind to underwater noise would be minimal in the 63Hz band being used to monitor anthropogenic noise levels. This contribution could be reduced further by limiting the comparison of ocean noise to days with similar ocean conditions and no higher than level 4 on the Beaufort Scale.

Result 2:

Mean underwater anthropogenic noise levels decreased at all oceanic sites during the lockdown period

Analysis from all hydrophone stations revealed a decrease in the geometric mean of noise levels during the COVID-10 lockdown period (Figure 4). The average decrease was 4.5 dB (decibels: a logarithmic scale) or 2.8 times decrease in sound intensity levels compared to a previous/subsequent year.

The peak decrease happened in the 2nd quarter of 2020, from April to June, coinciding with the peak 17% drop in marine traffic due to COVID-19 restrictions. The biggest drop of 6.9 dB happened at Georgia Strait, close to Port of Vancouver, the 3rd largest port in North America.



Wind speed correlates with underwater noise at frequencies > 125 Hz

Very weak Correlation (63 Hz) Weak Correlation (125 Hz) Moderate Correlation (500 Hz) Strong Correlation (1 kHz)

Light to moderate breeze (Beaufort Scale: 0 – 4) contributes minimally to the 10 Hz – 100 Hz band

Figure 3: The impact of wind on underwater noise is minimal in the 63 Hz third-octave band corresponding to anthropogenic noise.

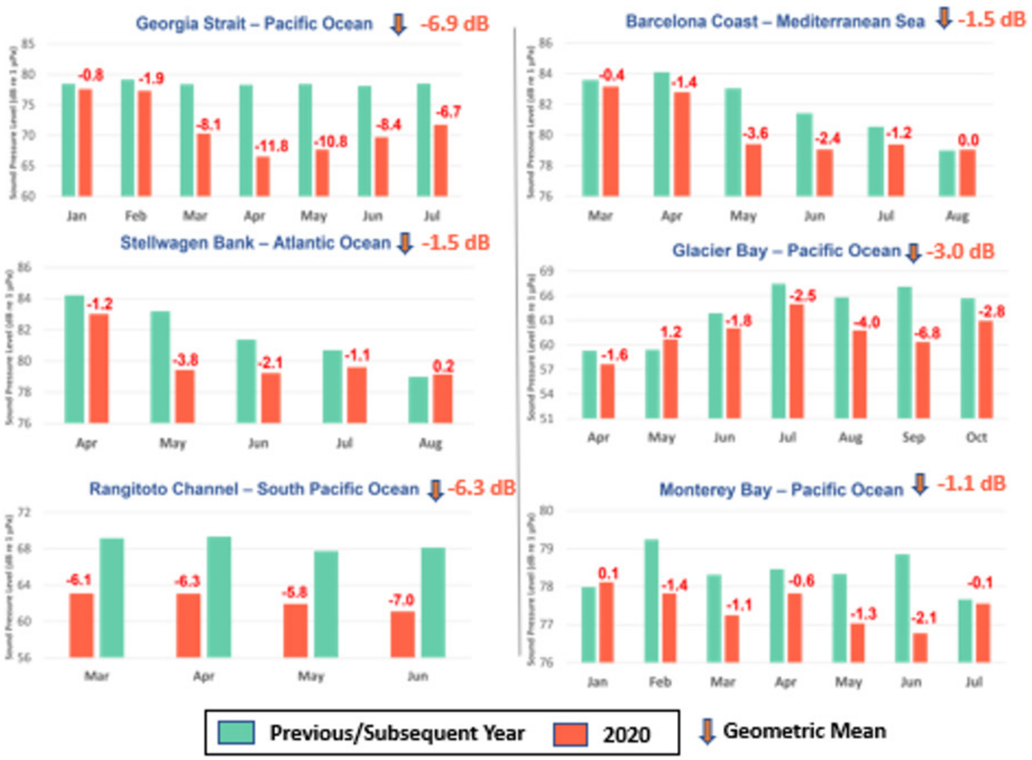


Figure 4: Decrease in mean anthropogenic noise levels in global oceans.

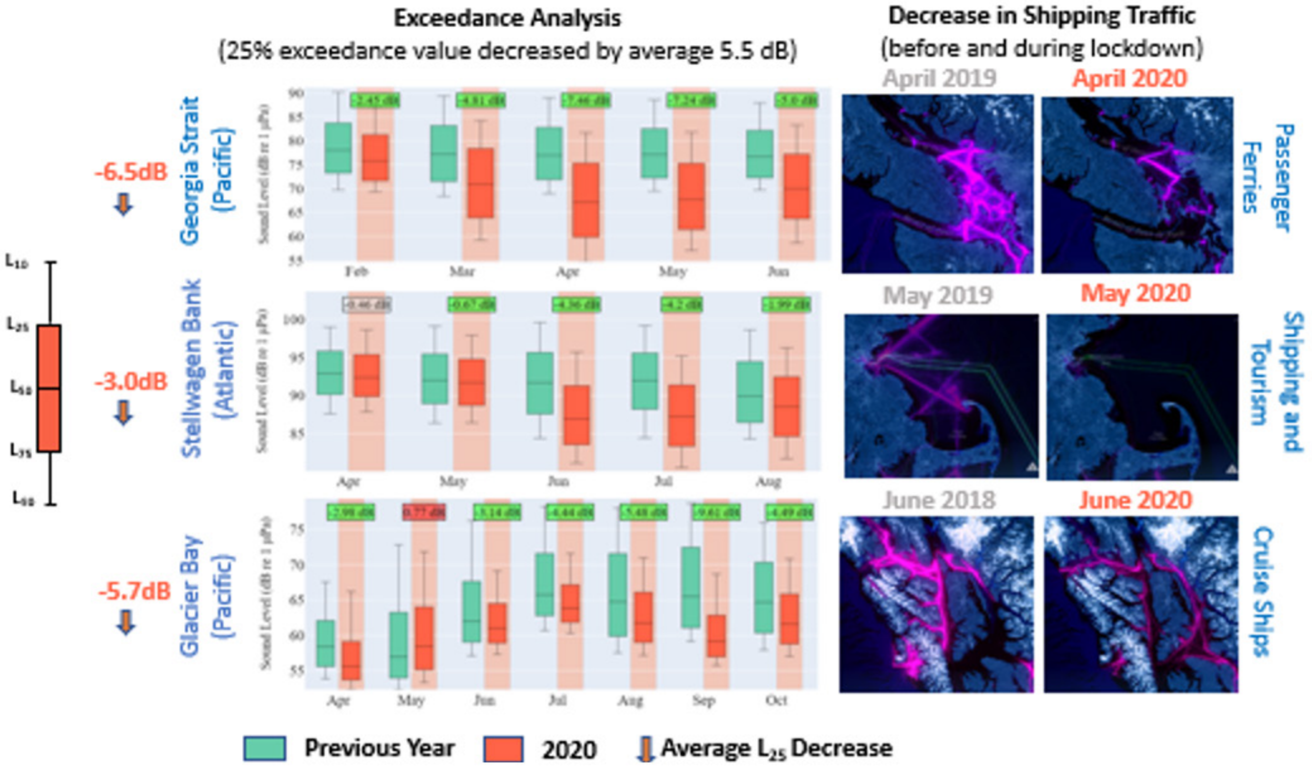


Figure 5: 25% Exceedance value analysis on the left shows a decrease in underwater ocean noise associated with marine traffic and is validated with shipping data from the Automated Information System (AIS) on the right.

DISCUSSIONS

Quantile Analysis: Noise Generated from Shipping Decreased

L25 exceedance analysis (the value above which 25% of sound pressure levels were found) – associated with shipping traffic decreased at all locations by an average of 5.5 dB during the lockdown period (Figure 5).

The drop was highest at oceanic locations served by commercial shipping, passenger ferries, and recreational or ocean cruises such as at Georgia Strait, Glacier Bay, and Rangitoto Channel in the Pacific Ocean. At Glacier Bay, a popular destination for cruise ships visiting Alaska, the peak drop coincided with the tourism months of June – September as the entire cruise season was canceled.

Validation of Results Using Satellite-based Shipping Data

The results of the study were validated by gathering data from the satellite-based Automated Identification System (AIS) that tracks the position of ships. It showed a distinct drop in marine traffic comparing April, May, and June 2019 data with 2020 data for all sites (Figure 5). This overlaps with the period of decrease in 25% exceedance values. It was clear that COVID-19 restrictions led to the silence of the global oceans, creating a temporarily quieter underwater world for marine mammals.

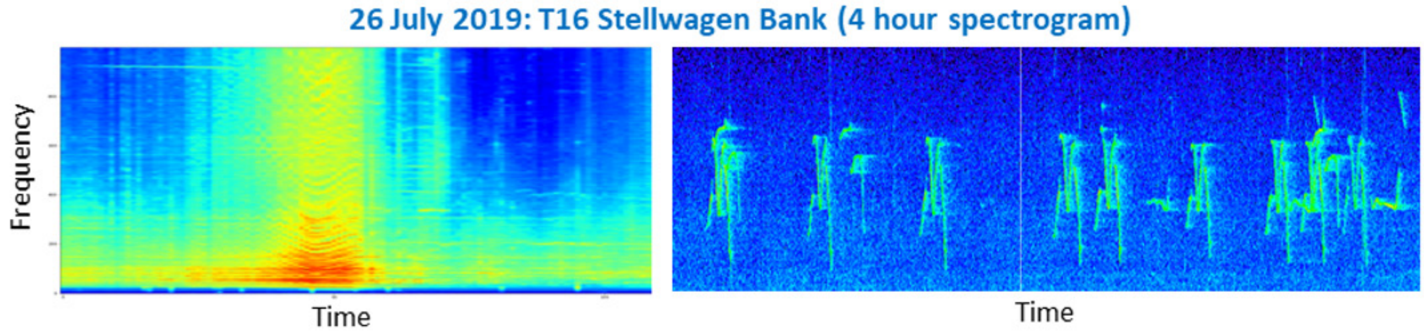


Figure 6: Spectrogram created from hydrophone data showing the existence of whistles of dolphins and the noises of ships.

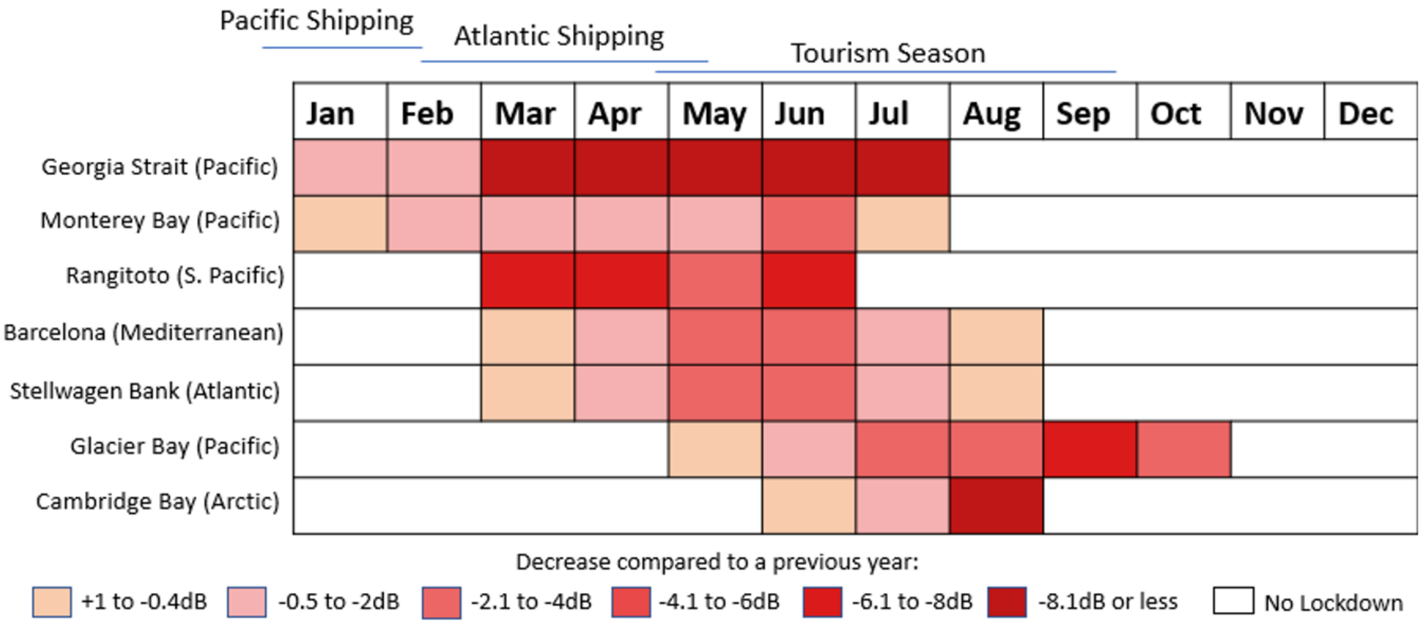


Figure 7: The 'Silence of Global Oceans' during the COVID-19 lockdown

Decrease in Anthropogenic Noise was Consistent with Findings from Other Studies

The decrease in underwater anthropogenic noise levels matched with studies carried out by the Oceans Networks Canada and National Oceanic and Atmospheric Administration USA at selected oceanic sites. A 2.7 dB decrease in median weekly power (100 Hz) over the first quarter of 2020 was noticed at Georgia Strait (Thomson & Barclay, 2021). In Glacier Bay, a 3 dB decline in median sound level (125 Hz) was observed in 2020 (Gabriele et al., 2021). Finally, at the Rangitoto Channel, 10 dB decline in the 25% exceedance level was found (Pine et al., 2021).

Overlap of Marine Mammals Vocalization with Shipping Noise Identified

During the analysis of spectrograms taken from hydrophones, signature whistles of dolphins and the noise of the ships were detected in the same spectrogram generated using Stellwagen Bank hydrophone data (Figure 6). While the ship noise lasted 1 hour, the whistles were heard for 1 minute. Whales, dolphins, and orcas can suffer hearing loss when exposed to loud underwater noises for extended periods.

ERRORS

Two possible sources of error were identified in the study. First, the sensitivity of hydrophones to sound measurements. While hydrophones are highly precise instruments, their sensitivity is limited by their resolution of: −200 dBV re 1 µPA @ 100 Hz, and the performance may vary in oceanic conditions versus laboratory conditions. Second, the uncertainties caused by wind speed in the sound level measurements were: ±0.19 dB @ 63 Hz or ±4%.

CONCLUSION

Commercial shipping dropped by 17% during the peak lockdown period. This led to a reduction in underwater ambient noise levels caused by human activities. Global oceans quietened during the lockdown period by an average of 4.5 dB, or 2.8 times decrease in peak sound intensity levels compared to previous years (Figure 7).

Once the pandemic restrictions were put in place, noise levels fell immediately. This shows that strategic “anthropause” such as moratoria in deep-sea mining, delay in tourism season, or shifting of shipping routes can be a strategy for reducing ocean noise during the breeding season and reversing the decline in marine population.

LIMITATIONS OF THE STUDY

As hydrophones operate at depths in open oceans, they sometimes malfunction, leading to gaps in continuous data in time-series analysis. A large volume of data recorded by hydrophones means many observatories cannot store and provide access to raw data archives. In some cases, hydrophone data is retrieved by ocean-going vessels and delays data by several months.

Outreach and Future

My research was selected for oral presentation at the Fall 2021 Meeting of the American Geophysical Union. On 14 December 2021, I gave an oral presentation of preliminary findings at the Ocean Observatories Initiative Facility Board Town Hall (OOIFB, 2021).

I have released the source code on GitHub and created an interactive WebApp www.MonitorMyOcean.com to monitor and compare anthropogenic noise levels in global oceans. It will allow data from other oceanic regions to be included in the analysis and create a community of ocean monitoring stewards who would be able to use open data and open algorithms to measure ocean noise.

The United Nations has proclaimed 2021–2030 as the UN Decade of Ocean Science for Sustainable Development. As a part of these activities, my web app www.MonitorMyOcean.com was endorsed by the Intergovernmental Oceanographic Commission (IOC) of UNESCO as a UN Ocean Decadal Activity. The project won Gold Medal at the Toronto Science Fair 2022, the Canadian Meteorological and Oceanographic Society (CMOS) Award, and the Second Grand Award at the 2022 International Science and Engineering Fair held in Atlanta, USA. It also won the EU Youth 4 Ocean Award, and I was invited to share my project findings at the UN Ocean Decade Conference 2022 in Lisbon from 27 June to 1 July 2022. Finally, my project was shortlisted for the Economist’s Ocean Changemakers Challenge 2022. I plan to expand the project to undertake an automated marine mammal census using acoustic signature identification.

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ABOUT THE AUTHOR - ARTASH NATH

Artash enjoys tackling complex inter-generational challenges using algorithms, computations and big data in oceans, space exploration, robotics, artificial intelligence, and quantum computing. He is the Grand Award Winner of the 2022 International Science and Engineering Fair and the 2022 EU Youth for Ocean Award winner. His most recent is MonitorMyOcean.com: which uses hydrophone data to measure the acoustic silence of oceans during the COVID-19 lockdown. The App got endorsed by UNESCO as a UN Decadal Activity, and presented his work at the UN Ocean Conference in Lisbon. In 2021, he created MonitorMyLockdown.com, which used seismic data to measure the effectiveness of COVID-19 lockdowns in real-time for 9 Canadian cities. The project won him the RISE 100 Award of the Schmidt Futures and Rhodes Trust, and was invited for three weeks to South Africa to collaborate with other global winners.