Shipping and Ice-Covered Waters – How Accurate Are The MSFD "Shipping Bands"?

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Abstract: *The EU Marine Strategy Framework Directive (MSFD) is an important tool in sustainable use of the oceans, addressing the UN Sustainable Development Goal SDG-14 "Life below water" and contributing to the Blue Economy. The definition of "shipping bands" at third-octave bands centred on 63 Hz and 125 Hz has been particularly useful to assess the impacts of marine traffic in different regions around Europe and in other oceans. Shipping is bound to increase in Arctic regions, as the next years will see amplified effects of climate change and easier access to ice-covered waters, sometimes with the total disappearance of ice in summer. We present here a test case in the shallow waters of Cambridge Bay (Nunavut, Canada), using measurements made available by Ocean Networks Canada and the Canadian Ice Service. We compare the months of August (little to no ice, and shipping activity) with the months of May (generally full ice cover and dynamic ice processes, but no shipping), between 2015 and 2020. Sound Pressure Levels and other metrics were derived with PAMGuide (Merchant et al., 2015, 2022), focusing on the "shipping bands". Individual ship signatures and general human impacts can be clearly identified and overall trends are compared with AIS data. As ice cover increases and shipping stops, the "shipping bands" are dominated by a variety of ice processes, and the comparisons between years shows interesting implications for the use of the MSFD in ice-covered waters. Monitoring of these bands also has direct implications for local communities and the fragile ecosystems present in Arctic waters.*

Keywords: *shipping, Marine Strategy Framework Directive, polar acoustics, ice acoustics*

1. RATIONALE

Shipping is an integral part of global trade and the Blue Economy is expected to double in size to $3tn by 2030 (https://www.oecd.org/ocean/topics/ocean-economy/). It is however associated to rising average sound levels [1-3]. This has led to concerns that the chronic presence of non-impulsive low-frequency anthropogenic noise may also affect marine species [4, 5] and there is a clear need for understanding these impacts in different environments and for setting clear guidance on acceptable sound levels.

The EU "Marine Strategy Framework Directive 2008/56/EC" (MSFD) is an important tool in the sustainable use of the oceans, providing a comprehensive series of metrics and contributing to addressing the UN Sustainable Development Goal SDG-14 "Life below water" (https://www.un.org/sustainabledevelopment/oceans/). Recently (December 2022), it was augmented by additional guidelines about setting threshold values for continuous underwater sounds [6], accounting for local conditions, acoustic baselines and marine life. The definition of "shipping bands" at third-octave bands centred on 63 Hz and 125 Hz has been particularly useful to assess the impacts of marine traffic in different regions around Europe and in other oceans (e.g. [7, 8] *inter alia*).

But how do these definitions fare in very different soundscapes? This is particularly important in the Arctic, as it is undergoing rapid climate change and increasing anthropogenic activities. Arctic amplification means polar regions are warming three times faster than the global average [9] and the Arctic seas are warming significantly down to depths of 700 m [10]. Between 1979 and 2019, the Arctic sea ice declined up to 43% in all regions, with sea ice becoming younger and thinner over this period [11, 12]. The gradual opening of the Northern Sea Route and the Northwest Passage is now associated with the distinct possibility of trans-Arctic routes in the near future [13], adding to existing shipping (Fig. 1) and therefore to its underwater impacts, especially if larger ships are also used.

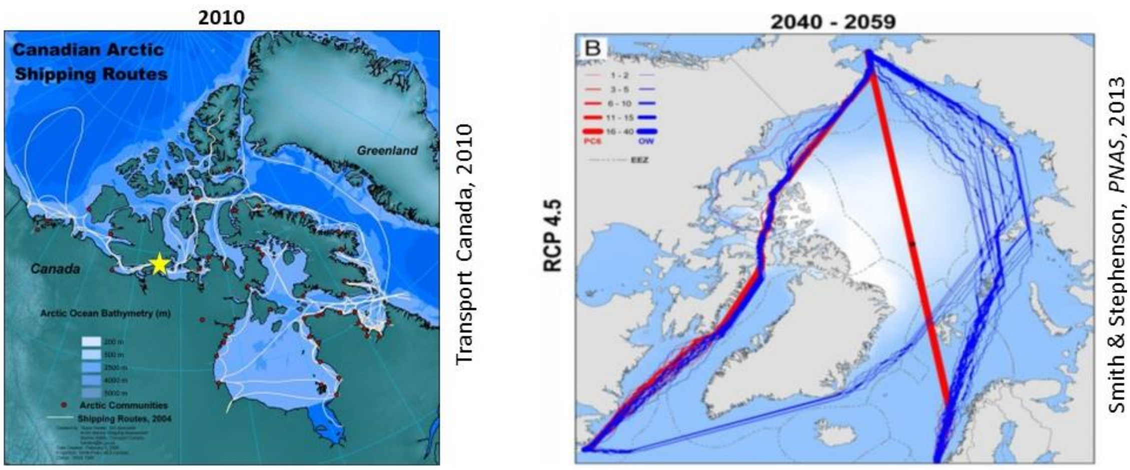

Fig.1: Left: shipping in the Canadian Arctic is well documented and following several routes (map from Transport Canada, https://tc.canada.ca/en/marine-transportation/arctic-shipping/canadian-arctic-shipping-routes, 2010). Cambridge Bay is indicated with a yellow star. Right: Arctic shipping is expected to increase as the ice cover decreases, especially along the coastlines and directly through the Arctic Ocean

(projections for a moderate climate change scenario, with Representative Concentration Pathway RCP = 4.5, by [13]).

The work presented here uses long-term acoustic measurements in Cambridge Bay (Nunavut, Canada), gathered by Ocean Networks Canada (ONC) as part of their Community Observatory programmes. The data are analysed for the months of May and August in 2015, 2016, 2018, 2019 and 2020. Their interpretations are informed by measurements of ice cover and concentration, at local and regional levels, coming from ONC direct measurements and daily syntheses of ice cover by the Canadian Ice Service. They will focus on the following questions:

- Can shipping signatures be identified in the "shipping bands" in this particular environment (shallow and Arctic)?
- Can daily summaries be used to automatically identify shipping activity?
- When there is maximal ice cover (and therefore no shipping), how do "shipping bands" perform?
- Is there already a noticeable trend from year to year in the amount of shipping and its underwater acoustic impact?

2. METHODOLOGY

Ambient sounds were measured at the seafloor observatory operated by Ocean Networks Canada, 8 m deep in Cambridge Bay. The hydrophone sensitivity is -170 dB re. 1 μPa. Audio data were in lossless WAV format for all years where data was recorded, and in lossless FLAC format for 2020 (converted to WAV), with a lower frequency limit of 10 Hz and upper frequency limit of 32 kHz (Nyquist frequency). The acoustic data is divided into time segments of 1 second, filtered with a Hann window with 50% overlap and processed with PAMGuide [14] and different metrics (like third-octave PSD and SPL) then aggregated every 5 minutes. Spectrograms and Empirical Probability Densities show the acoustic complexity and variations of these environments with seasons (Fig. 2). The months of August and May were selected as, for each year, they corresponded to the minimal and maximal levels of ice, respectively.

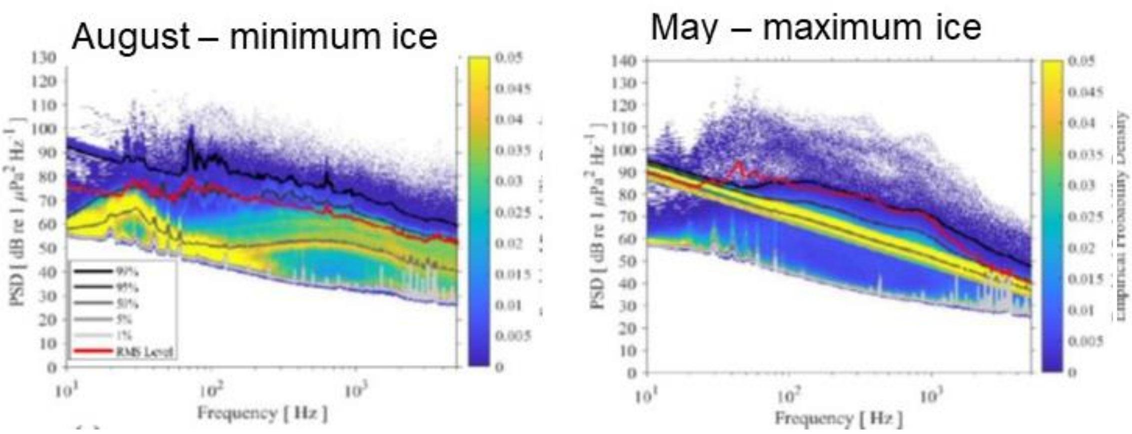

Fig.2: Seasonal variations are mostly related to the level of ice cover and to shipping. From [15].

Ice cover is measured locally, with an ice profiler attached to the hydrophone frame, showing the presence of any ice above the hydrophone and its thickness, and made available by ONC. This was the primary means of deciding which months were selected for endmembers of ice cover. Ice satellite charts are available from the Canadian Ice Service [16], daily for the August months and weekly for the Math months, showing amounts of ice cover and types of ice (using the WMO Egg Code to provide a numerical value of ice thickness). Ice thickness during winter months is also available from the Canadian Ice Service, measured directly from ice auger drillings. Typical data is presented in Fig. 3. Other ONC measurements include temperature and salinity (not directly used in the present study).

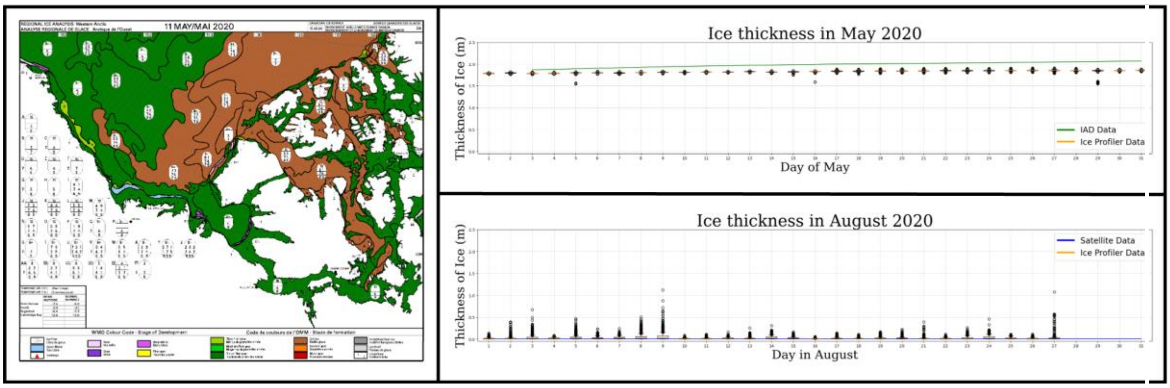

Fig.3: Ice measurements were obtained at regional and local scales. Left: Regional ice chart for 11th May 2020 [16]. Cambridge Bay (lower right of the chart) has thick first-year ice, noted as dark green. Right: ice thickness was measured by Ocean Networks Canada directly above the observing station with ice auger drilling (IAD) and upward-looking acoustic ice profiler (in May 2020) and with satellite measurements and ice profiler (in August 2020).

3. RESULTS

Sound Pressure Levels were systematically computed for the third-octave bands centred on 63 Hz and 125 Hz, often called the “shipping bands”. Boxplots are used to show the averages for each day, the lower and upper quartiles, and outliers are plotted as individual crosses (Fig. 4). The May months are all flat and uniform, whereas August data often shows larger data spreads. In May 2018 (Fig. 4, bottom), some days show larger spreads associated with smaller numbers of measurements (possibly due to equipment issues). Analyses of full spectrograms confirm there is no shipping during these months, agreeing with the presence of thick ice all over. The lower outliers (< 53 dB, Sea State 0 according to the Wenz curves) are interpreted as a reduction of the natural ambient noise by the ice cover. August months usually sport larger spreads of SPLs, associated with shipping and other human activities during part of the day (as evidenced by spectrograms) and often higher average levels if this activity lasts for a significant portion of a day. It is therefore relatively straightforward to identify days with shipping. The high numbers of outliers during the months of May however warrant further investigation.

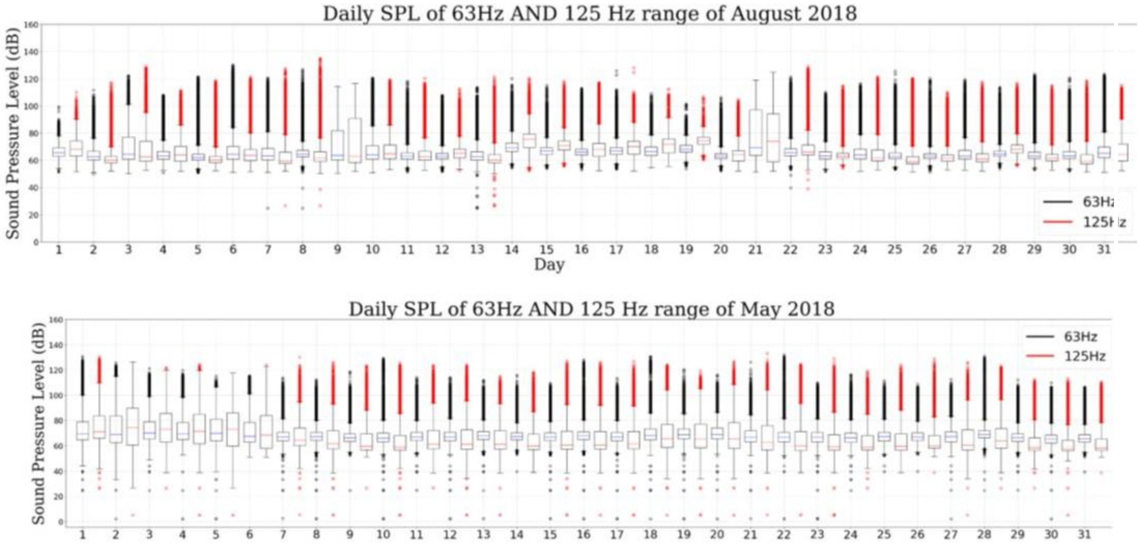

Fig.4: Example Third-Octave Levels for 2018, contrasting August (top: occasional shipping and minimal to no ice) with May (bottom: no shipping and maximal ice).

Scatter plots of SPLs in one "shipping band" respective to the other are useful to show these variations. These plots (Fig. 5-6) show SPLs colour-coded by years. A straight line has been added to better see whether SPLs are lower in one third-octave band or the other; points below the line show SPLs are higher at 63 Hz, whereas points above the line show higher SPLs in the 125-Hz band. Grey shading indicates SPLs louder than expected for natural sounds, based on the Wenz curves, and expected SPLs for the different sea states are indicated as individual points in the lower left of each scatter plot.

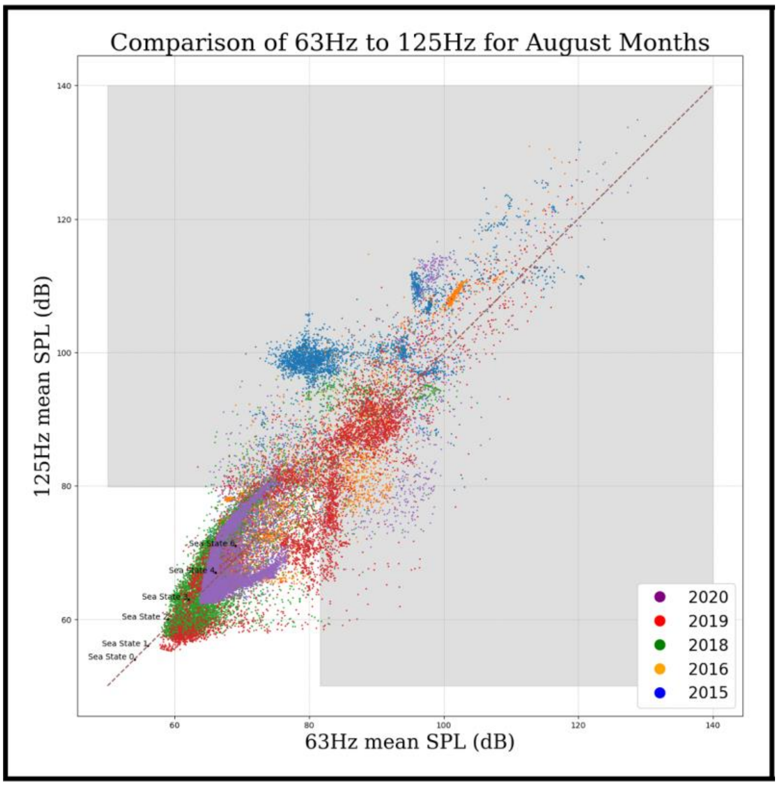

Fig.4: Evolution of sound levels in the "shipping bands" during successive summers (little to no ice cover).

During the months of August (Fig. 4), the SPLs show a great variation along each side of the straight line: shipping levels are sometimes louder in the 63-Hz band and sometimes louder in the 125-Hz band, in line with other observations of shipping noise in shallow waters (e.g. [7, 8]). Individual clouds are clearly visible (e.g. higher levels in 2015) and interpreted as individual ships based on the spectrograms: these ships can often be heard coming and returning, with associated variations in SPLs as they get closer to the measuring hydrophone. The numbers of ships each year was not large enough or variable enough [17] to meaningfully assess associated variations in acoustic impacts, with 9-38 ships recorded each year, including during Covid restrictions.

Conversely, during the months of May (Fig. 5), SPLs are grouped along the straight line, showing they are nearly equal in both frequency bands and with much smaller spread. They are often louder than expected in specific Sea States. When there is no shipping, because of the ubiquitous ice cover, these "shipping bands" are still loud enough and variable enough that they need interpreting with caution, looking at other third-octave bands. Here, other human activities (e.g. snowmobiles on the surface of ice) can be discounted because of the differences in time-frequency signatures (e.g. [18]). Our analyses instead show these louder sound levels are associated with other loud levels in the frequency bands associated with ice processes (collisions, shearing, cracking etc.) [15].

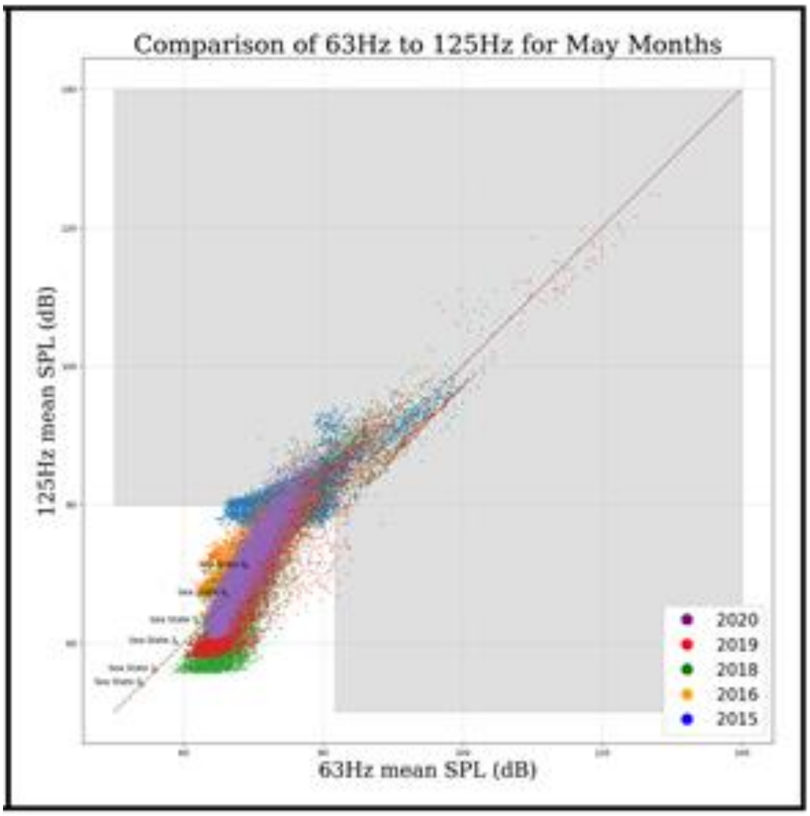

Fig.5: Evolution of sound levels in the "shipping bands" during successive winters (no shipping, maximum to full ice cover).

4. CONCLUSION

Climate change and potential increases in shipping in the Arctic were the key motivation to assess the role of the MSFD "shipping bands" in settings very different from its original areas of application, and rapidly evolving. We used long-term acoustic measurements made by Ocean Networks Canada at its Cambridge Bay community observatory, supplemented with ice profiler data, ice auger drilling and satellite charts from the Canadian Ice Service, to assess variations in "shipping bands" in August (little to no ice, shipping) relative to May (extensive to full ice, no shipping).

Shipping signatures can readily be identified by temporally continuous, loud levels of both "shipping bands" in this particular environment (shallow and Arctic), and this is confirmed by direct analyses of the spectrograms. Daily summaries with boxplots showing averages, lower and upper quartiles and outliers, can be advantageously used to identify days with shipping activity, for example to readily assess any increase in shipping levels over large timescales. In this particular case, the low levels of shipping identified by AIS [17] do not show yearly trends, although analyses of higher-frequency sounds are now being conducted to assess noise from other types of human activities. When there is maximal ice cover (and therefore no shipping), "shipping bands" show generally similar levels, with a very narrow spread, with outliers associated with ice processes (as corroborated by analyses of more third-octave bands). This article shows the usefulness of these "shipping bands" at 63 Hz and 125 Hz and how their relative levels vary. The results also show that, in shipping-free, ice-covered environments, these bands should be used with caution and supplemented with measurements at other third-octave bands.

5. ACKNOWLEDGEMENTS

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