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MITIGATION OF UNDERWATER SOUND LEVELS WITH BUBBLE CURTAINS DURING RESURFACING OPERATIONS OF THE PIERS AT THE PORT OF GROS-CACOUNA

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Abstract: Protection of marine mammals in the vicinity of human activities has been a growing concern in Canada over the past decade. Construction activities, oil and gas exploitation, container boats can all have direct impacts on marine mammals such as beluga whales and dolphins. As part of maintenance of the installations of the port of Gros-Cacouna, Quebec, the sidewalls of the piers were resurfaced on a total depth of 9 m. Cofferdam were built 2 meter away from the piers to allow access to the sidewalls in “dry dock”. The resurfacing operations required the removal of a 25 cm thick layer of concrete from the sidewalls with power tools. Using an OceanSonics hydrophone, it was confirmed that the main sources of underwater noise in the harbour were jackhammers, gas-powered concrete saws and air hoses. It was required to maintain ambient sound levels below a median value of 102 dB re 1 µPa immediately outside the harbour. The project requirements additionally specified that if it were impossible to remain below this value at all times, sound-emitting activities were to be performed only during the October 1st to March 31st period. Other sound level parameters such as SEL_{cum} and SPL_{peak} were measured and monitored over the course of the project.

Because the stringent requirements for the protection of wildlife proved difficult to attain, a 30 m long BubbleTubing® was deployed in a crescent shape at approximately 5 m from the cofferdam to provide additional sound level control. The BubbleTubing® produces a dense “curtain” of rising bubbles that interacts with sound. Experimental results from this field project showed a global attenuation of the order of 10 dB. These results are analyzed in light of a controlled test phase conducted previously in 2018 in the Bedford Basin located in Halifax, Nova-Scotia. This case studies demonstrates that a bubble curtain can be an asset to protect marine mammals from underwater construction works.

1 PROJECT OVERVIEW

Over the summer of 2018, the port of Gros-Cacouna underwent major maintenance work during which the sidewalls of the piers were to be resurfaced. GKM Consultants was brought in to measure underwater sound levels and provide long term monitoring for the protection of marine wildlife in the Saint-Lawrence River. With a total depth of 9 meters, the work had to be executed in a cofferdam. The cofferdam walls were built 2 meters away from the piers for the workers to safely access them. The operations involved removing the first 25 cm from the wall with power tools including gas saws and jackhammers. Because beluga whales, a protected species, live in the Saint-Lawrence River estuary, sound level measurements were part of the initial project requirements as demanded by the federal government. Median ambient sound level limits were 102 dB re 1 µPa immediately outside the harbour. The project requirements additionally specified that if it were impossible to remain below this value, sound-emitting activities were to be performed only during the October 1st to March 31st period. Other sound level parameters such as SEL_{cum} and SPL_{peak} (U.S. Department of Commerce National Oceanic and Atmospheric Administration National Marine Fisheries Service 2016) were measured and monitored over the course of the project.

In collaboration with the contractor, GKM Consultants designed a monitoring system and implementation program that took into account both the project requirements and the client's budgets and manpower availability. After the initial measurement campaigns, it was shown that during certain operations, the sound levels exceeded the norms to be met for the protection of wildlife. In order to alleviate the issue, a method which has seldom been used in Quebec was introduced; bubble curtains produced using BubbleTubing® perforated aeration tubes. The tubing was manufactured by Canadianpond.ca. In this case study, we discuss the situation that led to the deployment of this technology, why it was chosen and what lessons were learned from this unusual project.

2 DEPLOYMENT

The use of bubble curtains to attenuate underwater noise levels has been reported in several locations from projects in the North Sea and the Baltic Sea. Following up on early work performed in the 1970s, recent studies conducted in Germany and the UK have shown that it is possible to generate an insertion loss of several dB by deploying bubble curtains around underwater noise sources. Preliminary work conducted by GKM Consultants in the Bedford Basin, Nova-Scotia has shown that bubble curtains can attenuate sound levels significantly over certain frequency ranges, as shown in figure 1. Attenuation of 10 to 20 dB was measured over the 100-1000 Hz range and up to 80 dB at high frequency. Though the exact mechanisms at work have not been fully investigated in the scope of this preliminary work, these measurements laid the groundwork for proposing this approach for projects like that of Gros-Cacouna.

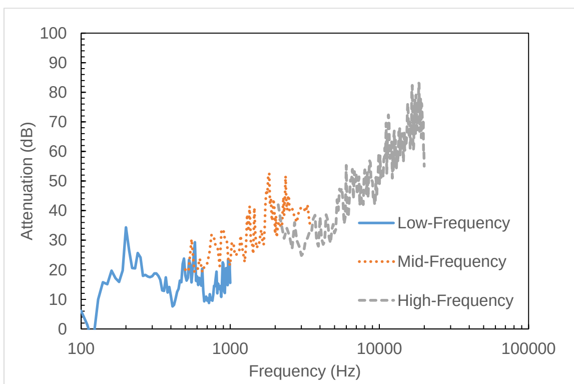

Figure 1: Attenuation spectrum of bubble curtains as measured by GKM Consultants

Several acoustics-related conditions need to be met to justify the use of bubble curtains. There has to be an overlap between the frequency bands emitted by human activity, the frequency bands that the animals respond to and the frequency range over which the bubble curtain is effective. In the same way that weighting curves (e.g. A-curve) have been designed for humans, M-curves were designed for marine mammals. Beluga whales are affected by sound emitted in the 500 to > 20,000 Hz range as shown in figure 2 (right axis). The figure also shows a typical measurement of sound emission from demolition activities in the absence of a bubble curtain as measured in the early phases of the Gros-Cacouna project. It can be seen that there is some overlap between the three curves. Sound emission levels of the demolition activities peak at around 500 Hz, where the beluga whale M-curve begins to pick up. Though it is not located within the bubble curtain's most effective range (i.e. high frequency), there is enough of an overlap to generate a net effect on M-weighted median sound levels. More advanced analyses of site- and tool- specific effects are beyond the scope of this work, but the deployment of the bubble curtains helped maintain sound levels at acceptable levels. Detailed specifications of the tubing can be found on the manufacturer's website. The tubing used has a 1" diameter with a very dense array of perforations along its length that generated bubbles that are 3-5 mm-wide each when they exit the tubing. The exact diameter of the bubbles depend on the depth of the tubing and the air flow and their diameter can be controlled to an extent. Additionally, the bubbles grow larger as they float to the surface. The bubble curtain itself is less than 5 cm wide at the tubing but a dispersion of up to 30 cm was observed by the time the bubbles rise to the surface.

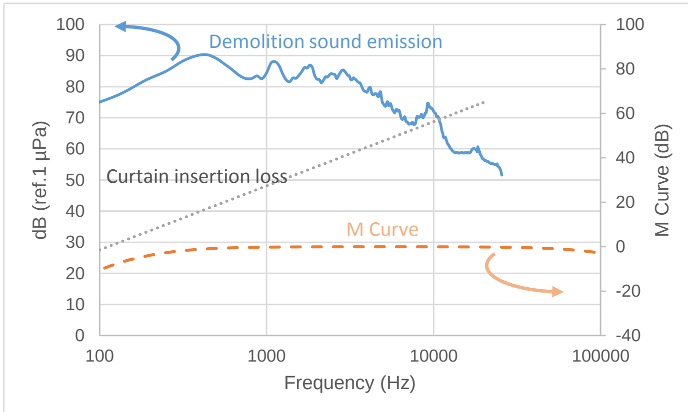

Figure 2: Comparison of (solid blue, left axis) a typical sound emission spectrum during the Gros-Cacouna project, (dotted grey, left axis) typical insertion loss of bubble curtains and (orange dashed, right axis) the M curve for beluga whales

3 INNOVATION

This project was one of the first to deploy bubble curtain technology in Canada for underwater noise mitigation. With the deployment of the bubble curtains, M-weighted median sound levels outside the harbour were reduced by 3 to 5 dB. The Gros-Cacouna project is a good case study for bubble curtains. In addition to meeting the aforementioned acoustic conditions, the physical conditions of the harbour are perfectly suited for this project. The shallowness of the harbour helps maintain a dense and uniform bubble curtain because bubbles expand and scatter as they rise to the surface. In other installations, such as on an oil rig, this could be circumvented by attaching bubble tubing at different depths. The harbour is sheltered, protecting the bubble curtains from winds and currents. Finally, the harbour is largely enclosed, already providing physical barriers to sound propagation into the river.

4 LESSONS LEARNED

It was shown that the sound level measurements conducted outside the harbour were occasionally exceeded during the first weeks of demolition. This could have prompted stoppage of the demolition work until a viable solution was found but practical limitations of the sound level measurements prevented the project leaders from applying such a drastic measure. A first limitation was that the background median noise level was often close to, and sometimes even higher than the limits stated in project requirements. It was therefore difficult to ascribe non-compliance specifically to the demolition activities. This was in part exacerbated by a second limitation: deploying the hydrophone in a satisfactory way proved challenging and was only finalized sometime after the beginning of the project. Figure 3 shows a schematic of the installation method, which requires to anchor the hydrophone loosely, to weigh it down and to have a buoy attached to it. In this way, the hydrophone is floating at a desired depth while limiting parasitic noises from attachment chains, buoys or anchors. A final and third limitation was that there was no real-time feedback available. The hydrophone had to be deployed for hours at a time, the data retrieved and analyzed after the fact to obtain exact information on the effects of each day's activities. Future projects could require a more complete monitoring system, with a real-time component or at least remote transmission of data and we would be able to make use of this experience to obtain high-quality in-situ measurements.

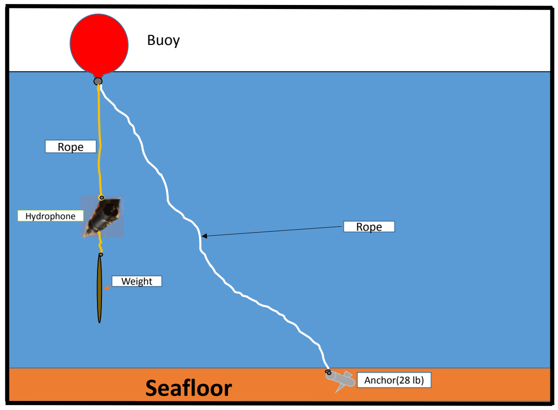

Figure 3: Installation schematics of the hydrophone

Several mitigation approaches were considered during planning phases: limiting the number of demolishers used simultaneously, using low-power tools or deploying mitigation measures such as bubble curtains. The first two solutions would have delayed the project significantly. Consequently, perforated tubes were procured before the start of the project, but they were not to be deployed before exceedances had been measured. Despite the real-life limitations of the measurements, it was deemed preferable to exert caution and deploy a cost-effective solution that would help meet compliance of noise emissions with respect to the project requirements. It was therefore cost-effective to proactively deploy a 30 m-long bubble curtain in a crescent shape 5 m away from the cofferdam. It was estimated that these dimensions would provide sufficient sound attenuation.

It was not possible to conduct sound level measurements during planning phases to correctly assess the sound emissions from the power tools because a cofferdam had to be built before any testing could be conducted. This could become a recurring situation in on-shore projects in which critical information could not be obtained before the start of the project. The data acquired over the course of this project will be re-usable in future projects to proactively design mitigation measures. To facilitate planning for contingencies, contractors who routinely perform on-shore work should maintain a database of past experiences and measurements, as well as simulation resources, to better manage risks associated to noise emission.

5 CONCLUSION

The Gros-Cacouna project offered the right conditions to deploy the bubble curtain technology. The site's physical properties, the sound levels to be obsearved and the type of work being performed all contributed to selecting this technology. Deploying bubble curtains provided several dB of attenuation helping the constructor to meet the requirements set for noise emission limits. Finally, the bubble curtain was deployed as a cautionary measure once non-compliance was confirmed.

6 REFERENCES

U.S. Department of Commerce National Oceanic and Atmospheric Administration National Marine Fisheries Service, *Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing*, NOAA Technical Memorandum NMFS-OPR-55, July 2016.