Passive Acoustic Monitoring of North Atlantic Right Whales using a Deformable Array

Dalhousie University N.O.I.S.E. Lab

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Background & Field Work

Figure 1. Major copepod prey species (*Calanus finmarchicus*) of the north Atlantic right whale.

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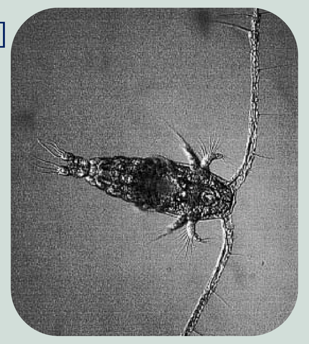

The endangered north Atlantic right whale's (NARW) summer feeding grounds have expanded northward is tow of *Calanus finmarchicus*, a copepodite prey species, whose habitat has shifted north due to warming oceans[2]. Over half of known NARW deaths in recent decades have been attributed to ship strikes and 83% of individuals experienced fishing entanglements at some point in their lifetime[1,3]. In 2017, 4% of the NARW population was killed by these anthropogenic threats. Heightened restrictions on industry in 2018 reduced the death toll to zero. Unfortunately, the shipping, fishing, and tourism sectors were displeased, and in 2019 the compromised medium level of restrictions led to 2% of the population being killed. The importance of striking a balance between industry and conservation is clear[4]. Passive acoustic monitoring overcomes many drawbacks of tagging and visual surveys and is the cheapest method in terms of dollars per detection[5].

The Royal Canadian Airforce and Dalhousie University put together a two-day data-blitz effort back in July 2018 to assess a strategy for the acoustic monitoring of cetaceans. They deployed a four-by-eight array of 32 sonobuoys from planes into the Gulf of St Lawrence. Sound pressure level and bearing information is streamed back to the plane through a radio signal. The planes and a boat performed visuals surveys for the duration of the experiment as well. The aim of this research is to describe the performance of large deformable arrays for passive acoustic monitoring and to quantify the array's effective detection range, localization accuracy and uncertainty as a function of size and number of elements.

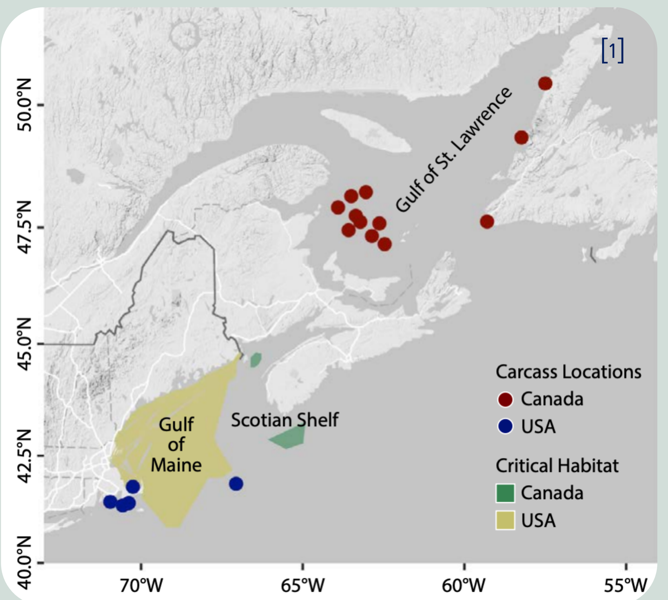

Figure 2. Map of north Atlantic right whale carcasses found in 2017. Data from NOAA and DFO.

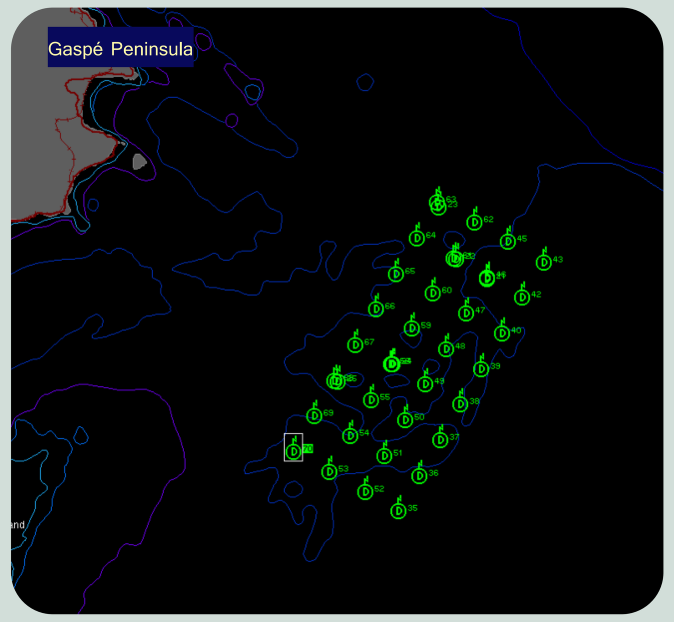

Figure 3. Map of experimental set up on July 30th displaying the drop positions of all sonobuoys used.

Data Processing

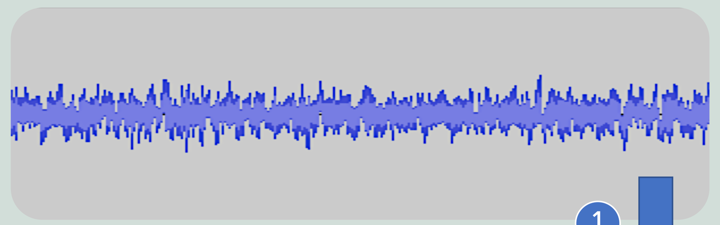

Figure 4. 0.1 second snippet of waveform data.

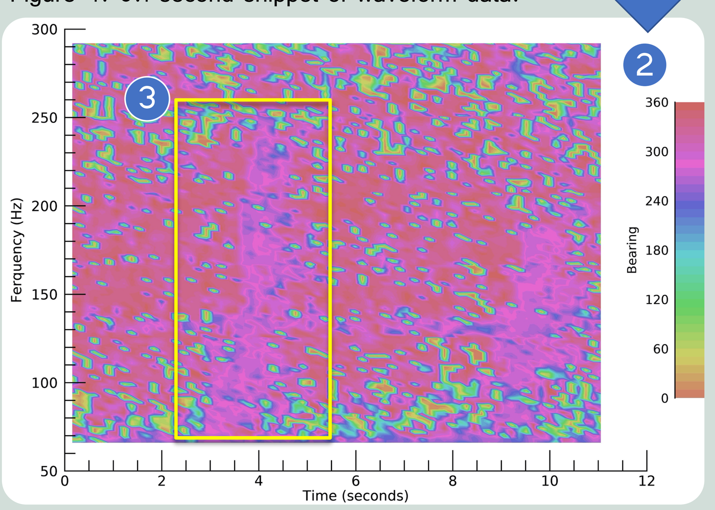

Figure 5. Azigram of two NARW upcalls with manual annotation boundaries represented by yellow box.

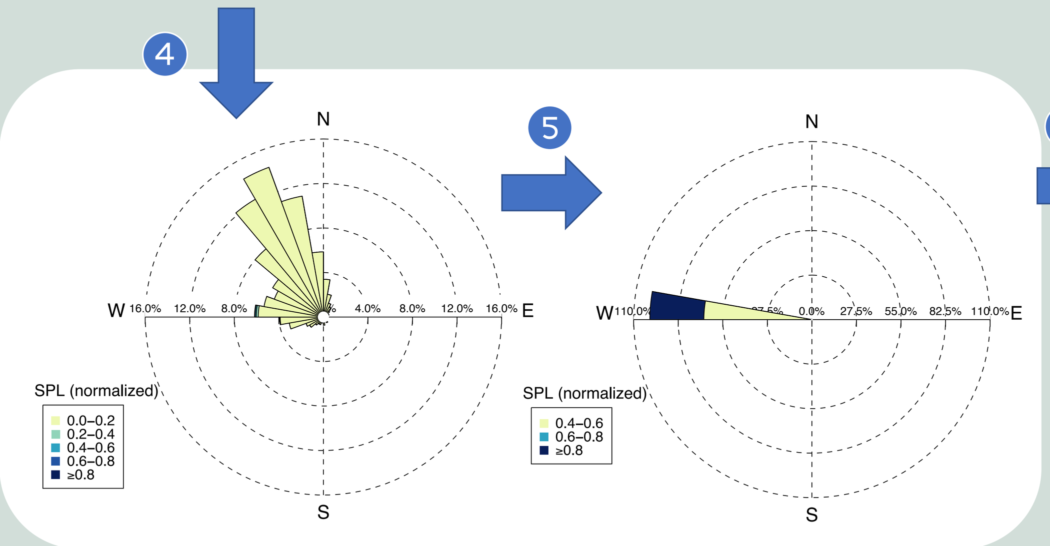

Figure 6. Windrose plots of the selected azigram area before (left) and after (right) filtering out ambient noise.

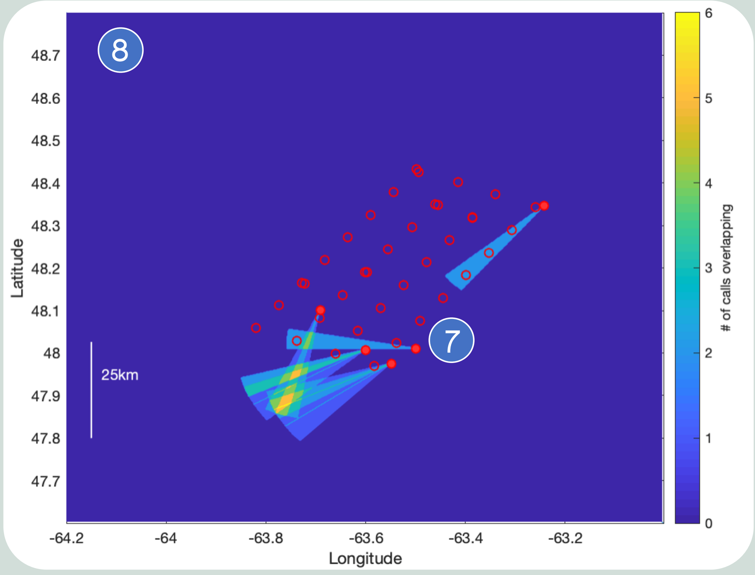

Figure 7. Heatmap of all north Atlantic right whale detections made from 18h10 to 18h20 on July 30th. Empty red circles represent drop positions of sonobuoys. Filled red circles represent updated positions of sonobuoys making detections.

1. Perform Fast Fourier Transform on directional acoustic waveform data to allow manipulation in time and frequency domains.
2. Create azigrams showing acoustic power in time, frequency and bearing to source.
3. Select data specific to each detection using manual annotations.
4. Organize selected data as windrose plots to display the frequency of occurrence, acoustic power, and cardinal direction.
5. Filter out ambient noise under the assumption of isotropic ambient noise.
6. Assign a bearing to source and updated GPS sonobuoy position for each detection (± 5° error).
7. Plot detection cone over study area with an angular width of 10° and a maximum nominal detection range of 28.6km.
8. Create heatmaps of whale position by overlaying all detections cones occurring every 10-minute throughout the experiment.

Results

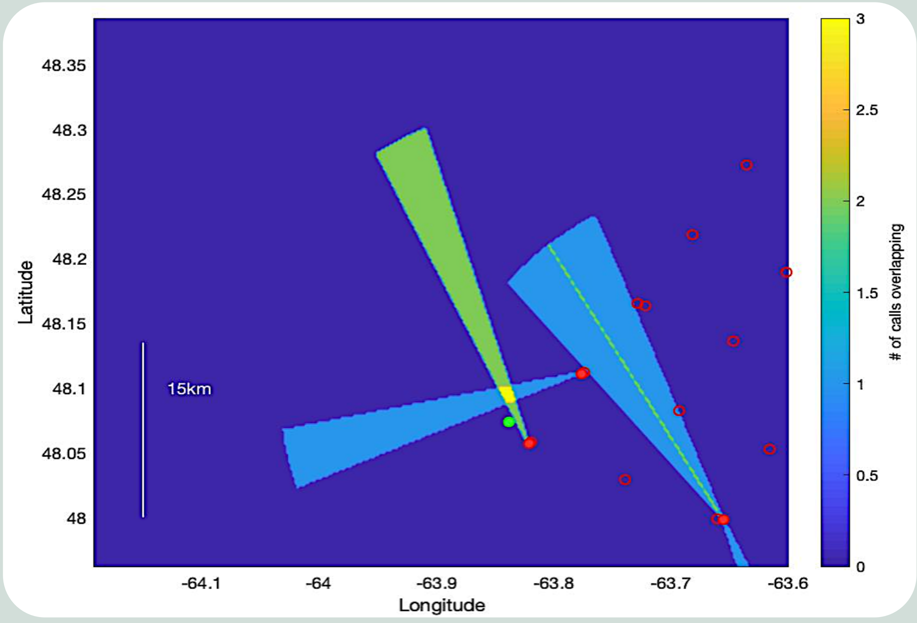

Figure 8. Cropped heatmap of the southwest portion of the sonobuoy array from 13h40 - 13h50 with a visual detection at 13h49 (green dot).

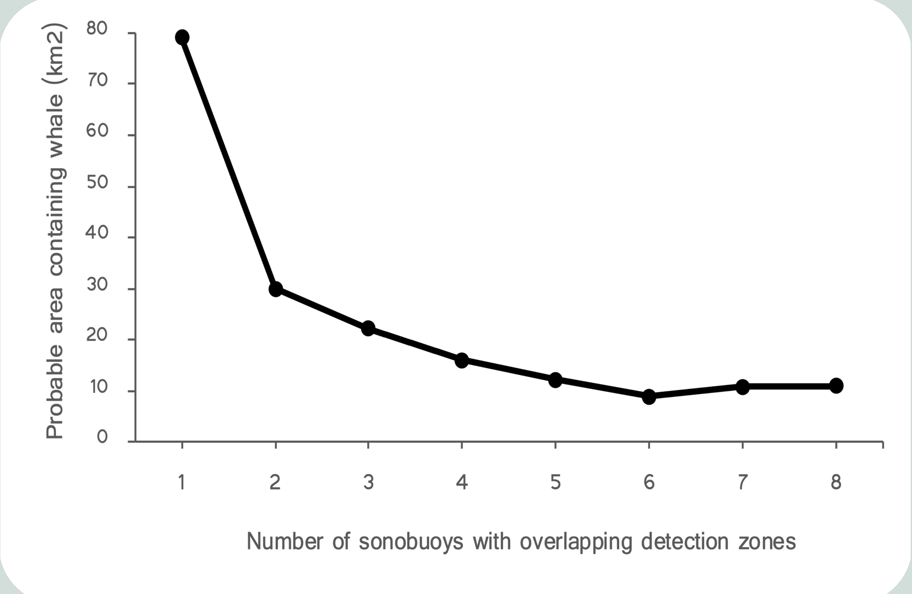

Figure 9. Area of probable localization of NARW surface active group in km^2 as a function of the number of sonobuoys making the detection.

Three visual detections were made during the 5.5 hours of audio recording on July 30th. Only one occurred at the same time as an overlap event. The distance from the centre of the acoustic detection to the visual detection is 2.37 km (Figure 8).

As the number of sonobuoys detecting the same sound increased, the precision of the acoustic detection increased. This effect was maximized at 6 sonobuoys (Figure 9).

A parabolic equation model equipped with bathymetry, sound speed profile, and ambient noise data calculated transmission loss in the study area. The probability that a NARW call originating from within the field be detected by any 2 sonobuoys is ≥ 50% (Figure 10).

According to the parabolic equation model, the probability that 6 sonobuoys detect the same call does not exceed 40% (Figure 11).

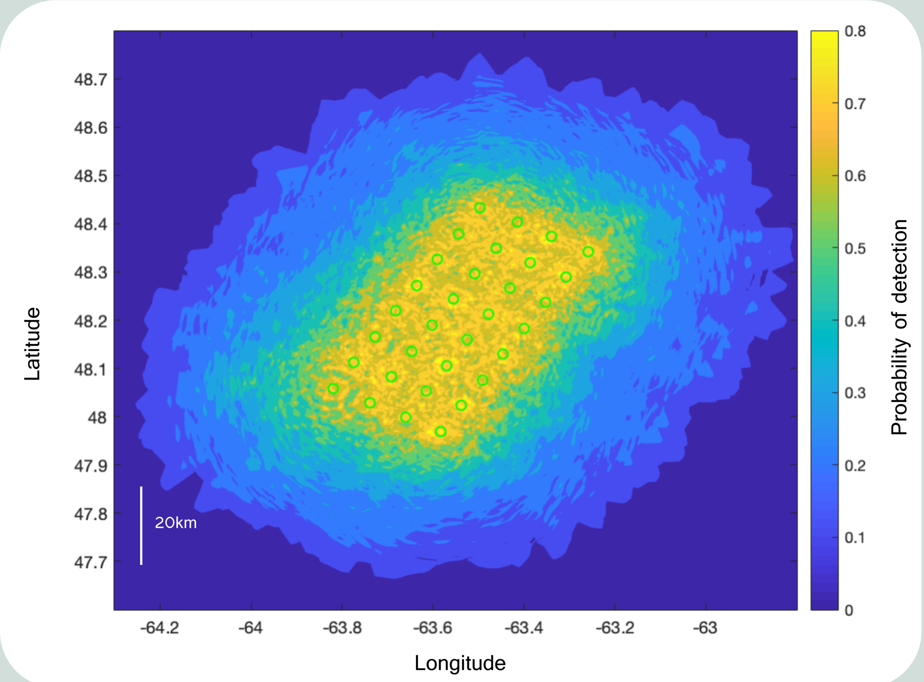

Figure 10. Probability of detection by any 2 sonobuoys in the array. Sonobuoys are plotted as green circles and positioned in their drop positions.

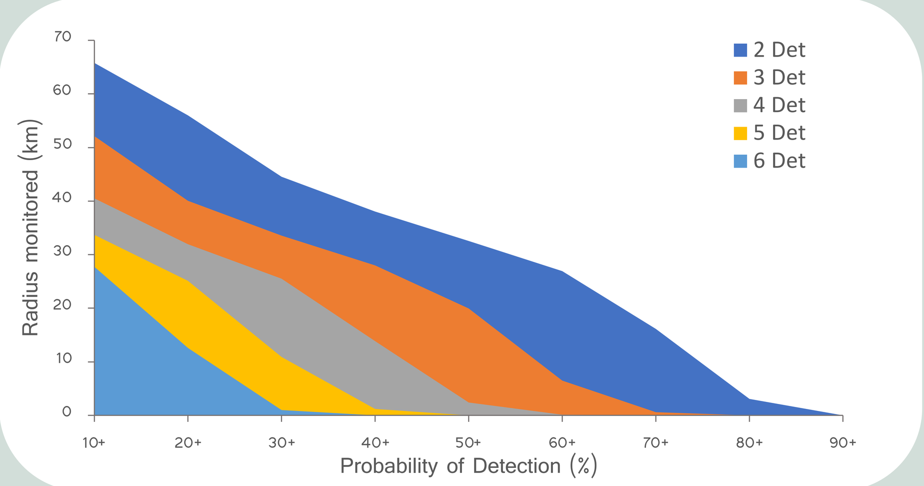

Figure 11. Area of array field monitored (radius in kilometers) simultaneously by 2,3,4,5 or 6 sonobuoys as a function of the probability (%) of detecting a NARW call.

Discussion

The single visual detection serves as an affirmation that whales were definitely in the area. However, the whale sited is not necessarily the whale detected acoustically.

A maximal precision at 6 overlapping detections suggests a hexagonal array of sonobuoys could lead to the greatest precision for the lowest cost. A probability of detection by 2 sonobuoys greater or equal to 50% is adequate for monitoring purposes[6]. If detection by 6 sonobuoys is the goal, then the proposed design for future arrays would have equidistant spacing with a hexagonal diameter equal to approximately 6.5km (the current spacing between any 2 hydrophones) (Figure 12).

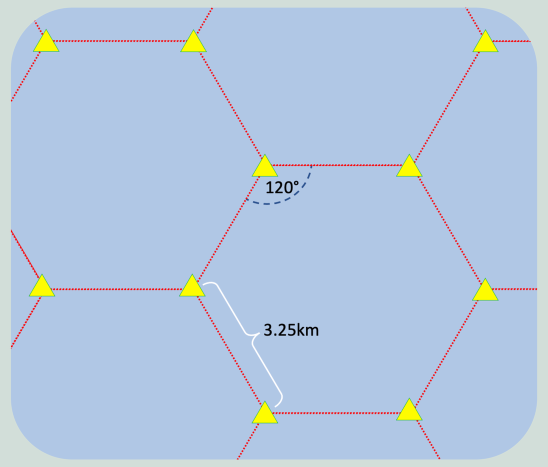

Figure 12. Proposed sonobuoy field, where yellow triangles represent sonobuoys.

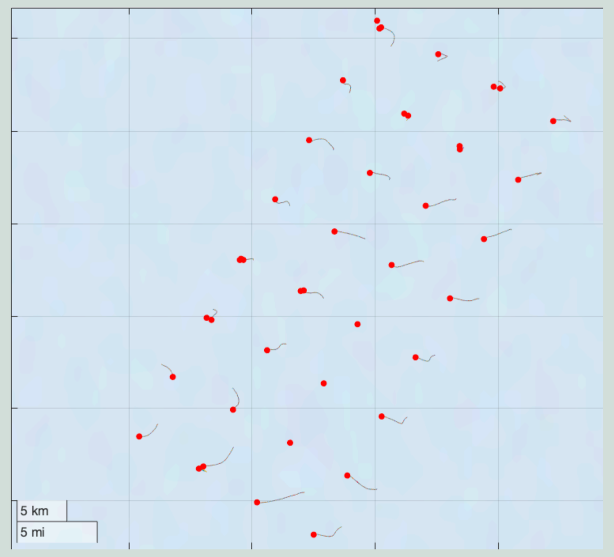

Figure 13. Drift paths of sonobuoys on July 30th. Red dots represent sonobuoy drop positions.

GPS tracks of the drifting sonobuoys from July 31st were unavailable. Due to the ~5km long and highly variable drift paths seen on July 30th, the lack of tracks on July 31st would have made those localizations inconsistent and inaccurate (Figure 13).

The 32-sonobuoy array used on July 30th had 5 failed sensors which had to be re-seeded. This is a 16% failure rate that without correction could lead to large data losses.

The DIFAR sonobuoys used in this experiment only record for 5 - 6 hours before sinking themselves. This is not practical for long-term monitoring

Conclusion

- This method of localizing north Atlantic right whales is suitable for obtaining a snapshot of cetacean presence and movement.
- Under optimal conditions, the probable area of a whale or group of whales localized using this technique can be as precise as 10 km^2 on average.
- The uncertainty of ± 5° in the direction of arrival of a whale call is the largest contributor to the positional uncertainty and is inherent to the DIFAR sonobuoy sensor.

Next Steps

- Using the parabolic equation model to calculate the probabilities of detection after the array has drifted for 5 hours. Comparing these results to current modelling results will reveal if array deformation with drift has a significant impact on detection efficacy.

References

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Acknowledgments

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