Volumetric Towed Hydrophone Arrays: Two alternative designs to improve localization

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INTRODUCTION

BACKGROUND
- Traditional hydrophone arrays with linear configurations cannot spatially discriminate the location of cetacean vocalizations.
- Previous sea trials on small research vessels showed that volumetric array prototypes with spatially-arranged hydrophones could successfully localize cetacean groups in three-dimensions. Excessive noise occurred at speeds higher than 6 knots.

APPROACH
- Re-design a volumetric array that can:
  1. Operate from large vessels at 10 kts
  2. Discriminate sounds from all directions
  3. Produce low flow noise and maintain stability
  4. Be easily handled by a single person
  5. Be compatible with existing NMFS PAM systems

METHODS

RESEARCH and DEVELOPMENT
- SolidWorks modeled two prototype designs.
- FloWorks simulations of fluid flow at 10 kts from different angles predicted values of torque, pressure, and shear stress.

RESULTS

X-ARRAY PROTOTYPE
- PVC array body cracked
- High levels of flow vibrational noise, noise increased with higher speeds
- Significant rotational movement (accelerometer data)
- PVC array body cracked
- High levels of flow vibrational noise, noise increased with higher speeds

TORPEDO PROTOTYPE
- Aluminum body remained intact
- Flow noise improved up to 9 kts, remained high < 7 kHz
- Improved rotational movement for speeds up to 6 kts (StarOddi sensors)
- Aluminum body remained intact
- Flow noise improved up to 9 kts, remained high < 7 kHz
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CONCLUSIONS
- Achieved vast improvements in the performance of both prototypes, but further modifications to the design are needed to:
  1. Increase functionality at 10 kts from larger vessels
  2. Collect more reliable data of rotational orientation
  3. Improve localization using volumetric arrays may enhance the utility of passive acoustics and significantly contribute to cetacean research.

REFERENCES AND ACKNOWLEDGMENTS


A special thanks to Seaborn Ahmad for dedicating his senior thesis to drawing and modeling our designs, to the engineers, Ben Price and Scott Jenkins, for building the prototypes, and to Jennifer Koontz and Emily Griffin for their crucial roles in small-scale funding for developing and testing the volumetric array was provided by Advanced Science Technology Working Group (ASTWG) of the National Oceanic and Atmospheric Administration.
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METHODS

RESEARCH and DEVELOPMENT
- SolidWorks modeled two prototype designs:
  - X-ARRAY
  - TORPEDO
- FloWorks simulations of fluid flow at 10 kts from different angles predicted values of torque, pressure, and shear stress.

RESULTS

SEA TRIALS – Evaluating Prototype Performance
- Conducted 7 field tests on vessels ranging from 65-209 ft
- Data collected:
  - Wave file recordings – assess flow noise levels
  - Accelerometer data – measure array rotational orientation
  - StarOddi sensor data – measure array tilt/orientation
- Modifications to prototypes implemented based on data analysis results

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FLOW NOISE
- Spectrograms display relative differences in noise levels between volumetric prototypes at 5 knots, post-modifications
- Comparison of noise spectra between volumetric prototypes and a linear array at low speeds up to 7 kts

ANALYSIS

FLOW NOISE
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  - StarOddi sensor data – measure array tilt/orientation

- Modifications to prototypes implemented based on data analysis results

FLOWS NOISE

TORPEDO ARRAY
- Spectrograms display relative differences in noise levels between volumetric prototypes at 5 knots, post-modifications

CONCLUSIONS

- Achieved vast improvements in the performance of both prototypes, but further modifications to the design are needed to:
  - Increase functionality at 10 knots from larger vessels
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  - Improving localization using volumetric arrays may enhance the utility of passive acoustics and significantly contribute to cetacean research.

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APPROACH

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  1. Operate from large vessels at 10 kts
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  4. Be easily handled by a single person
  5. Be compatible with existing NMFS PAM systems

METHODS

RESEARCH and DEVELOPMENT

- SolidWorks modeled two prototype designs.
- FloWorks simulations of fluid flow at 10 kts from different angles predicted values of torque, pressure, and shear stress.

SETRAIALS – Evaluating Prototype Performance

- Conducted 7 field tests on vessels ranging from 65-209 ft
- Data collected:
  1. Wav file recordings – assess flow noise levels
  2. Accelerometer data – measure array rotational orientation
  3. StarOddi sensor data – measure array tilt/orientation
- Modifications to prototypes implemented based on data analysis results

RESULTS

X-ARRAY PROTOTYPE

Initial Results
- PVC array body cracked
- High levels of flow / vibrational noise, noise increased with higher speeds
- Significant rotational movement (accelerometer data)

Modifications
- 4 fin structure added to aft end for stabilization
- 1 fin made of bismuth lead

Post-Modification Results
- Continual low flow noise levels up to 9 kts
- Improved rotational movement, but varied at different speeds (StarOddi sensors)

TORPEDO PROTOTYPE

Initial Results
- Aluminum body remained intact
- Flow noise improved up to 9 kts, remained high < 7 kHz
- Imposed rotational movement for speeds up to 6 kts (StarOddi sensors)

Modifications
- Replaced PVC body with aluminum body
- Potted hydrophone pods with polyurethane
- Secured hydrophone cables inside struts
- Replaced PVC array body with aluminum body
- Increased amount of lead weight in lower strut

Analysis

FLOW NOISE

- Spectrograms display relative noise levels between volumetric prototypes at 5 knots, post-modifications

CONCLUSIONS

- Achieved vast improvements in the performance of both prototypes, but further modifications to the design are needed to:
  1. Increase functionality at 10 kts from larger vessels
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  3. Improve localization using volumetric arrays may enhance the utility of passive acoustics and significantly contribute to cetacean research.

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BACKGROUND

Traditional hydrophone arrays with linear configurations cannot spatially discriminate the location of cetacean vocalizations. Previous sea trials on small research vessels showed that volumetric array prototypes with spatially-arranged vocalizations proved to be handled easily during deployment and retrieval on small and large vessels. Traditional hydrophone arrays with linear configurations could not achieve this.

RESEARCH and DEVELOPMENT

SolidWorks modeled two prototype designs. These were an X-Array and a Torpedo Array. Each was designed to:

1. Operate from large vessels at 10 knots
2. Be easily handled by a single person
3. Produce low flow noise and maintain stability
4. Be compatible with existing NMFS systems
5. Collect more reliable data of rotational orientation

METHODS

SEA TRIALS – Evaluating Prototype Performance

Conducted 7 field tests on vessels ranging from 65-300 ft

Data collected:
- Wave file recordings – assess flow noise levels
- Accelerometer data – measure array rotational orientation
- StarOddi sensor data – measure array tilt/orientation
- Modifications to prototypes implemented based on data analysis results

RESULTS

X-ARRAY PROTOTYPE

Initial Results
- PVC array body cracked
- High levels of flow vibrational noise, noise increased with higher speeds
- Significant rotational movement (accelerometer data)

Modifications
- Replaced PVC body with aluminum body
- Extended one pair of struts to 90 cm
- Increased amount of lead weight in lower strut

Post-Modification Results
- Aluminum body remained intact
- Flow noise improved up to 9 kts, remained high < 7 kHz
- Improved rotational movement for speeds up to 6 kts (StarOddi sensors)

TORPEDO PROTOTYPE

Initial Results
- Outer shell flooded easily upon immersion
- Low levels of flow noise
- Significant rotational movement (accelerometer data)

Modifications
- 4 fins structure added to aft end for stabilization
- 1 fin made of bismuth lead

Post-Modification Results
- Continued low flow noise levels up to 9 kts
- Improved rotational movement, but varied at different speeds (StarOddi sensors)

Flow noise

Comparison of noise spectra between volumetric prototypes at 5 knots, post-modifications

Flow noise

Spectrograms display relative differences in noise levels between volumetric prototypes at 5 knots, post-modifications

CONCLUSIONS

Achieved vast improvements in the performance of both prototypes, but further modifications to the design are needed to:
- Increase functionality at 10 knots from larger vessels
- Collect more reliable data of rotational orientation

Improving localization using volumetric arrays may enhance the utility of passive acoustics and significantly contribute to cetacean research.

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Thank you!