FINAL PROJECT REPORT (v1.4)

OERA Pathway 2020 Program

Field Assessment of Multi-beam Sonar Performance in Bottom Mount Deployments

OERA Project number: 200-219

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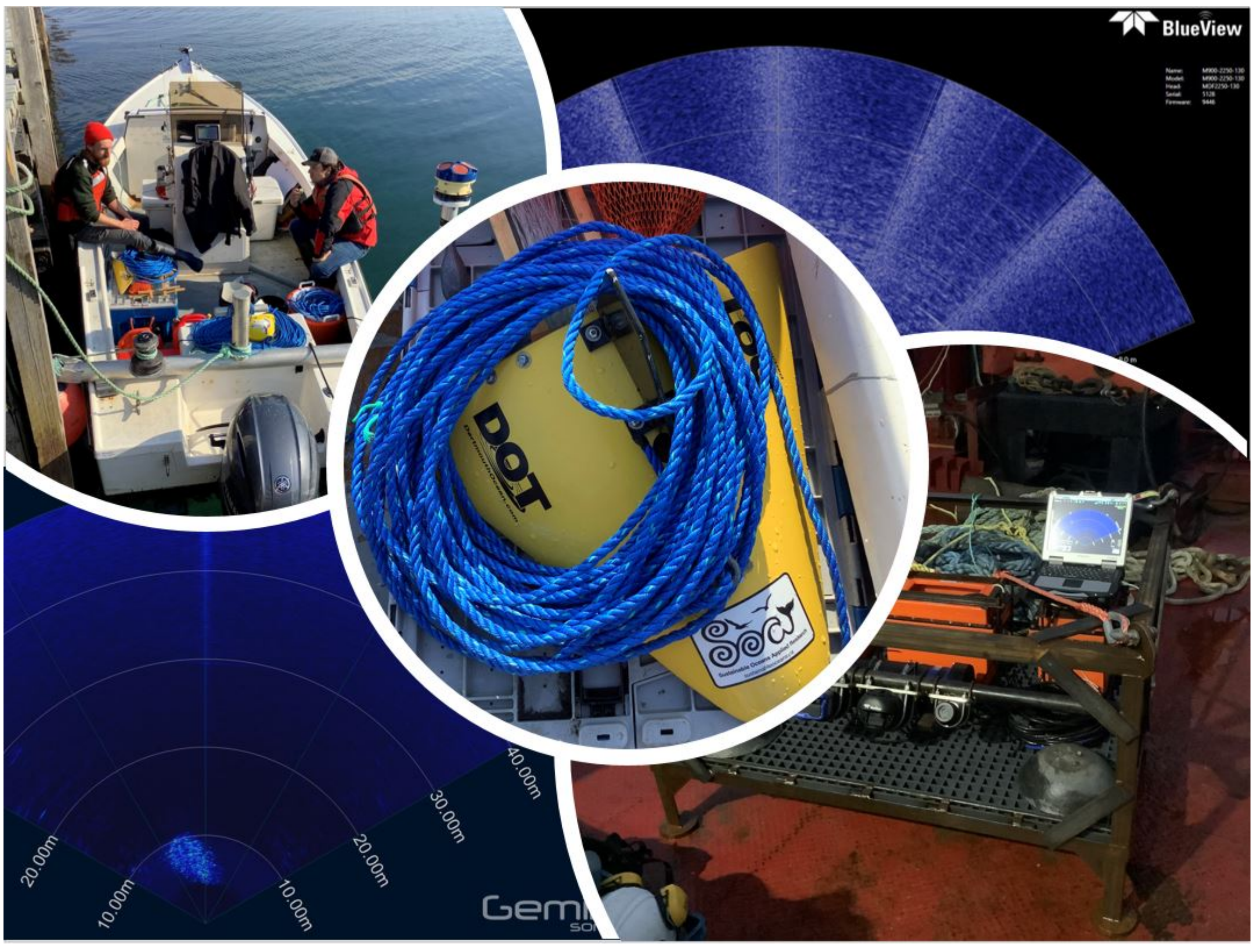

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Executive Summary

Multibeam imaging sonars have application to monitoring fish and marine mammal presence and behaviours in the near field of tidal turbine installations, including evaluating avoidance, evasion, and potential blade strikes. SOAR conducted field experiments to help reduce uncertainty in performance of the Tritech Gemini 720is and Teledyne Blueview M900-2250 multibeam imaging sonars for identifying and tracking discrete targets in high-flow environments. This information will help inform the Department of Fisheries and Oceans Canada, tidal energy developers, and other stakeholders in the design and implementation of effective monitoring systems for tidal energy projects in the Bay of Fundy and beyond. These two imaging sonars were the technologies recommended for testing by the subject matter expert for imaging sonars during the first phase (Global Capability Assessment) of the Pathway Program. The Tritech Gemini 720is operates at 720 kHz and has a maximum effective sampling range of approximately 50 m. The Teledyne Blueview M900-2250 has operating frequencies of 900 or 2250 kHz, with a 10 m range for the high frequency transducer head. As per the recommendation from the Global Capability Assessment, this report focuses on the Blueview's capabilities while operating at 2250 kHz.

Field trials included deployments of an Autonomous Multibeam Imaging Sonar (AMIS) monitoring system in Grand Passage. The depth at the deployment location is approximately 25 m at low water, with flow speeds up to approximately 2.5 m/s. The deployed sonars were oriented with their ensonified areas directed downstream. The instruments' horizontal fields of view oriented across-channel and vertical fields of view tilted upward from the bed.

Three targets were used during data collection: a 0.45 kg (1 lb.) (9.5 cm long x 3.8 cm max diameter) lead fishing weight, approx. 12 cm diameter basalt rock in a lobster bait bag, and a V-Wing glider (approx. 50 cm diameter) from Dartmouth Ocean Technologies. The targets were suspended beneath research vessel Puffin while drifting through the study area. The Puffin repeatedly travelled to a position upstream from the sonars, then drifted with the tidal flow such that the drift trajectory allowed the targets to pass through the sonars' ensonified areas. The AMIS system was fully autonomous, so no live view of data collection was available.

The data were manually analyzed to evaluate the performance of the Gemini and Blueview multibeam imaging sonars for detecting and tracking targets in strong tidal flow. The visualization and organization of the data were conducted using the proprietary software

packages associated with each sonar: Gemini SeaTec and Teledyne ProViewer. Data from the Gemini were exported into video and organized into training and test data sets, which were shared with 7 sonar observers who conducted the manual analysis to detect, track, and identify the targets. Links to the training and test data sets for are provided below.

Gemini training data	https://vimeo.com/483141927
Gemini test data with 50m range	https://vimeo.com/483142328

Due to the small ensonified area of the Blueview, insufficient sightings of known targets were collected to generate training and test data sets. A manual analysis was conducted by SOAR, with a focus of events of concurrent detection by the Blueview and Gemini including natural targets (primarily fish) and occasionally the artificial targets used in our methodology. A link to a video file with 21 comparative cases is provided below.

Concurrent Blueview and Gemini	https://vimeo.com/487808248

The Tritech Gemini 720is received high scores from the observers in the ability to identify the presence of, visually detect, and track targets in videos displaying sonogram data output. The observers correctly identified the presence of a target in 99% of cases, and gave average scores greater than 4 out of 5 describing their visual detection and tracking ability. Targets were correctly identified roughly 50% of the time. No significant relationship between flow speed and ability to detect and track the targets was observed.

The Teledyne Blueview M900-2250 MKI is an impressive technology that offered the ability to resolve finer scale features of the targets and their movements in some cases. However, persistent high-noise bands resulting from a known hardware issue and an apparent transducer alignment issue represented substantial impediments to reliable target detection and tracking. We conclude that data from the Blueview did not add substantial value or insight to the target analysis when used in conjunction with the Gemini. This should not rule out potential use of other MHz frequency multibeam sonars for monitoring the 10 m range in a combined sonar approach, including MKII of the Blueview.

SOAR recommends use of the Tritech Gemini 720is for application to monitoring interactions between marine animals and tidal turbines. The Gemini demonstrated a high level of utility for detecting and tracking targets from vessel and bottom mounted orientations in tidal flows up to approximately 2.5 m/s in Grand Passage. It is likely that this technology will contribute significantly to effective monitoring and advancing knowledge of importance to regulators and other stakeholders. Tidal flows are faster at the FORCE site in the Minas Passage, with flow speeds exceeding 2.5 m/s 30 to 40% of the time.

With respect to deploying multibeam sonars from the surface (i.e., vessel) or seabed, the sonars performed well from both positions, despite increased levels of air entrainment in the vessel mount case. The selection of deployment position for monitoring tidal turbines is likely to be defined by the nature of the tidal device (floating or seabed mounted) and the questions to be addressed by the monitoring.

The project addressed the objective of assessing the performance of bottom deployed multibeam imaging sonars for target detections, including the extent of signal interference from waves/turbulence, and entrained air.

Further testing of bottom mounted multibeam sonars would be useful in four focus areas, including:

1) fish and other marine animals in locations and seasons (times) with high levels of animal abundance and variety,
2) evaluating most effective sonar orientations for monitoring the near field of tidal turbines,
3) flow speeds that exceed 3 m/s, and
4) increasing efficiency in data assessment, possibly including reliable automation.

This work should build upon success in Grand Passage to conduct next steps in stronger flows present in Petit Passage and Minas Passage. The report titled “Field Assessment of Multi-beam Sonar Performance in Surface Mount Deployments” (Trowse et al. 2020) provides similar analysis for the case of surface mounted Gemini 720is and Blueview M900-2250.

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Acknowledgments

SOAR thanks the following support organizations and supply chain who helped us deliver on this work:

- Offshore Energy Research Association of Nova Scotia
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- Clare Machine Works
- Luna Sea Solutions
- MarineSitu
- Mi’kmaw Conservation Group
- Fundy Ocean Research Centre for Energy (a.k.a. FORCE)
- Dasco Equipment Inc.
- Tritech and Teledyne technical support staff
- Canadian Hydrokinetic Turbine Test Centre

1.0 Introduction

Multibeam imaging sonars have application to monitoring fish and marine mammal presence and behaviours in the near-field of tidal turbine installations, including evaluating avoidance, evasion, and potential blade strikes (Hastie 2013; Viehman and Zydlewski 2014; Bevelhimer et al. 2016; Williamson et al. 2016, 2017; Sanderson et al. 2019). However, there is uncertainty in performance of these instruments in high-flow environments due to turbulence and associated entrained air in the water column, where a reduction in instrument efficacy may result from scattering of the transmitted acoustic signal through turbulent zones of the water column before the signal reaches potential targets, with further signal dilution on the return to the transducer (Melvin and Cochrane 2014). Some specific and additional challenges include a) mounting sonars at sufficient depth in high-flow environments to reduce exposure to entrained air, b) achieving optimal orientation such that the area of interest is ensonified while minimizing acoustic returns from surface and/or seabed, and c) transferring, storing, and efficiently analyzing large amounts of data.

Several makes and models of multibeam imaging sonars are available, with a major source of difference being the frequency at which they transmit acoustic energy. Higher frequencies are associated with shorter wavelengths, which results in resolution increasing with frequency, and range decreasing with increasing frequency. The combined use of kHz and MHz frequency range multi-beam imaging sonars is of interest for monitoring marine animals because it offers potential for an instrument package to detect and track targets at ranges up to approximately 50 m with identification (and/or finer scale tracking) of targets at a range up to approximately 10 m. For environments with suitable visibility, the addition of an optical camera offers increased potential for target identification, target validation, and tracking at ranges of approximately 0.1 to 15 m in very clear waters.

As part of the Pathway Program, SOAR conducted work to help evaluate the performance of the Tritech Gemini 720is and Teledyne Blueview M900-2250 (2250 kHz transducer head) multibeam imaging sonars for evaluating interactions between marine animals and tidal turbines. This information will help inform the Department of Fisheries and Oceans Canada (DFO), tidal energy developers, and other stakeholders in the design and implementation of effective monitoring systems for tidal energy projects in the Bay of Fundy and beyond.

The Tritech Gemini 720is multibeam imaging sonar has been used by MCT Seagen in Strangford Lough (Hastie 2013), OpenHydro at the Fundy Ocean Research Centre for Energy (FORCE) (Viehman et al. 2017), and other applications including studies commissioned by FORCE (Gnann 2017). With an operating frequency centered at 720 kHz, the Gemini has a target detection range of up to 100 m (Cotter, et al. 2017) but has reduced resolution in comparison to higher frequency systems. The dual frequency Teledyne Blueview M900-2250 has two sets of transducers, one set centered at 900 kHz (close to the Gemini) and the other set at 2250 kHz (2.25 MHz). Use of the Blueview 2.25 MHz transducer head may have application in shorter range monitoring, up to approximately 10 m (Cotter et al. 2017). These two imaging sonars are the technologies recommended for testing by the subject matter expert for imaging sonars during the first phase (Global Capability Assessment) of the Pathway Program (Joslin 2019).

SOAR's work in 2020 has included data collection and analysis from near surface (vessel mounted) and seabed deployments. This report covers the methodology and results for the bottom mounted experiment. "Field Assessment of Multi-beam Sonar Performance in Surface Mount Deployments" (Trowse et al. 2020) discusses the vessel mount deployment (vessel mount project).

The **objective** of the work covered in this report is to assess the performance of seabed deployed multibeam imaging sonars for target detections, including the extent of signal interference from waves/turbulence, and entrained air.

The **expected outcomes** include**:**

- Primary - Report on performance of bottom deployed multibeam imaging sonars for target detections, and a recommendation on whether the use of bottom deployed multibeam imaging sonars is feasible for monitoring interactions between marine animals and tidal turbines.
- Secondary - Data sets to support further research (beyond the scope and timeline of this project) including potential for calibration of multibeam imaging sonars, quantification of the effects of air entrainment on target detectability, and autodetection and classification algorithms (software).

2.0 Methodology

The methodology was developed to evaluate the performance of two multibeam imaging sonars when deployed on the seabed, including the Tritech Gemini 720is (Gemini) and the dual frequency Teledyne Blueview M900-2250 MKI (Blueview). The Gemini has 512 beams aligned along a 120° swath width (angular resolution of 0.25°), with each beam having a 20° width perpendicular to the swath. The Blueview has 768 beams aligned along a 130° swath width (angular resolution of 0.18°), with each beam having a 20° width perpendicular to the swath. Multibeam sonars resolve target locations as range along each beam. The resulting composite (by combining all beams) is used to generate a sonogram with target locations in the swath width but does not resolve target location in the beam width. For this experiment, the sonars were both aligned such that field of view had swath width on the horizontal plane (parallel to water surface) and beam width on the vertical plane (depth). The acoustic frequency and geometry of the ensonified area for each sonar are summarized in Table 1. The Subaqua SAIS IP Cam (optical camera) and a GoPro were included for target verification, and to demonstrate ability for targets to be identified optically.

Table 1: Multibeam imaging sonar frequency and ensonified area

Sonar	Frequency (kHz)	Range (m)	Swath width (degrees)	Beam width (degrees)
Gemini	720	120 m(1)	120	20
Blueview	900 or 2250(2)	10	130	20

Notes:

- The Tritech supplied specifications for the Gemini report a max range of 120m, however the maximum effective range for monitoring marine animals in tidal channels is 50 to 60 m.
- The Blueview is dual frequency, with two transducer heads. Our work focused on the high frequency capabilities with the 2250 kHz (2.25 MHz) transducers, and associated range of 10 m. For brevity, ongoing reference to the Blueview in this report implies the high frequency transducer head.
- Both sonars transmit a “chirp” pulse that spans a range of frequencies, centered at the values listed above.

2.1 Instrument Configuration and Deployment

SOAR worked with Dalhousie Ocean Acoustics Laboratory, Clare Machine Works, and Dasco Equipment to design and build an Autonomous Multibeam Imaging Sonar (AMIS) monitoring system including the bottom lander/frame with sonar mounts, power supply (three 24 V Deepsea Power and Light SeaBattery Power Modules), subsea data acquisition system (sonar control and data storage with an Intel NUC computer and power conditioning inside a Nortek 500 m depth rated pressure case with custom end cap), and custom cables for power supply and communication. The frame also carried 140 kg of lead ballast. The AMIS monitoring system is shown in Figure 1.

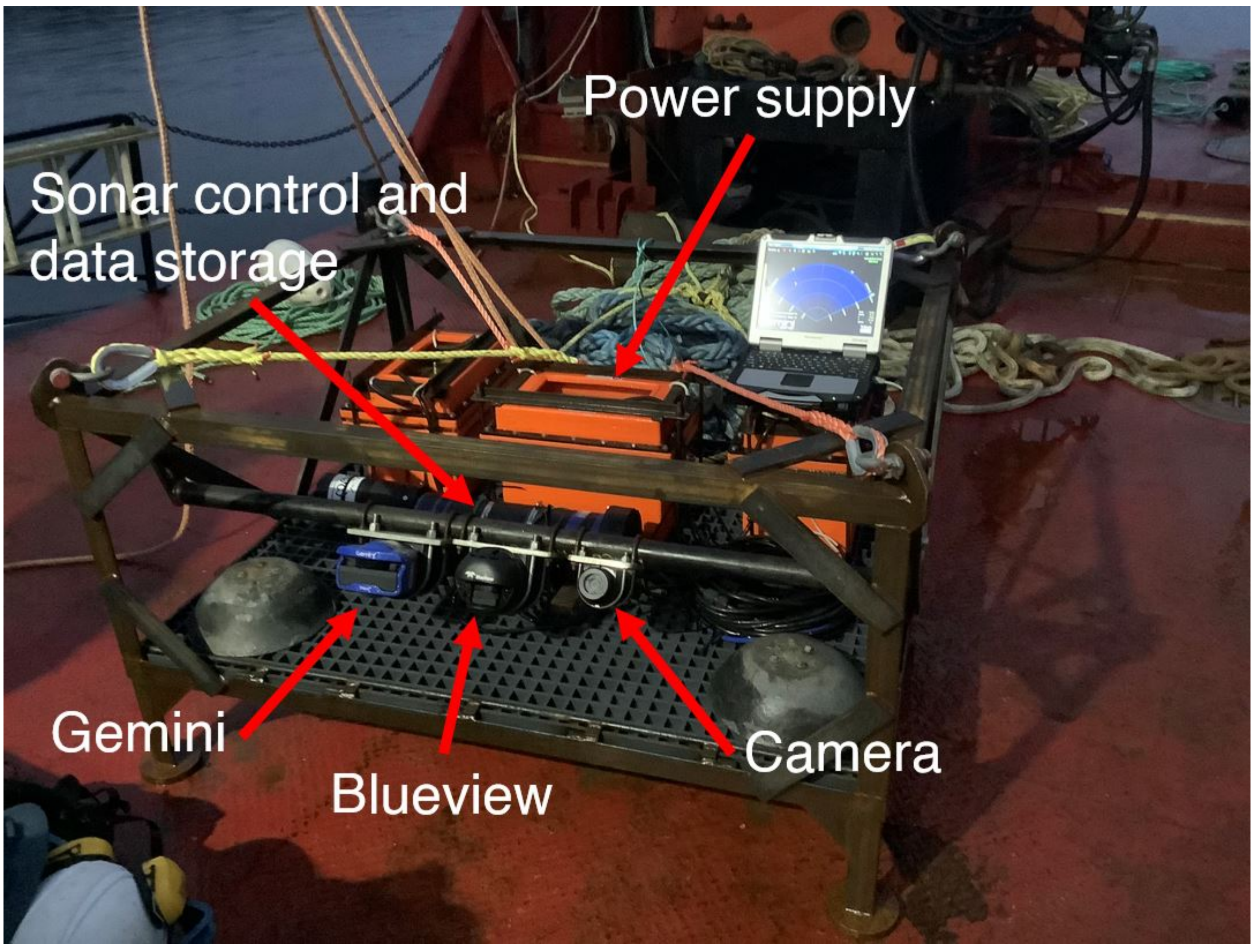

Figure 1: Autonomous Multibeam Imagining Sonar (AMIS) monitoring system

Submergence tests were conducted in Westport Harbour prior to each of two principal deployments in Grand Passage. The submergence tests allowed for a) testing and refinement of the mounting arrangement and sonar angles, b) testing the subsea data acquisition system, and

c) refinement of the deployment methodology. A time-lapse video of frame assembly and harbour testing is available at: https://vimeo.com/488171392

The vertical tilt angles of the sonars were refined to avoid or limit acoustic returns from both the seabed and the AMIS instrument frame (see the horizontal frame member above the sonars in Figure 1), which imposed lower and upper constraints on the range of possible sonar orientations, respectively. During the harbour testing, efforts were made to remove or reduce the acoustic returns from the AMIS frame by changing the tilt angles and positions of the sonars. However, returns from the frame were found to persist unless the transducer heads were positioned outside of the frame's perimeter, increasing the risk of damage to the sonars. The frame-returns do not appear to create an acoustic shadow, suggesting they may be related to the presence of acoustic sidelobes outside of the principle 20° beam width.

The principal experiment consisted of two deployments in Grand Passage, on 2020-10-20 and 2020-10-22, hereafter referred to as Deployments 1 and 2. The deployment location is shown in Figure 2. On both occasions, AMIS was deployed during low water slack and retrieved during high water slack, data being collected during the flood tide. The depth at the deployment location is approximately 25 m at low water, with flow speeds up to approximately 2.5 m/s. A video of the deployment is available at: https://vimeo.com/483103490.

The deployed sonars were oriented such that their ensonified areas were directed downstream, with the instruments' horizontal fields of view oriented across-channel. The configuration was chosen to minimize limitations of the ensonified areas by the sea surface or bottom, while maximizing the horizontal (i.e., downstream) extent over which targets would be visible if drifting downstream at a fixed depth. The horizontal alignment of the instruments was accomplished through use of a ground line and clump weight, which were attached to the AMIS frame. The weight and ground line were lowered first, upstream of the target location for the instrument frame, so that the taught ground line would ensure the correct orientation of the frame when it reached bottom. For both deployments, a diver verified the orientation of the frame and made minor adjustments, and confirmed that no boulders or other obstructions were apparent in the field of view. The diver reported the frame to be sitting well on relatively level ground (less than approximately 5° slope) in both cases.

For Deployment 1, the Gemini was tilted such that the vertical beam width spanned from 5 to 25° above the horizontal plane of the instrument frame. The vertical field of view of the Blueview spanned 20 to 40°. The sampling range of the Gemini was set to 30 m with an associated sampling rate of 13 to 14 Hz, and the range for the Blueview set to its maximum of 10 m with an associated sampling rate of 15 to 16 Hz. For Deployment 2, both sonars were tilted such that their ensonified areas spanned from 15 to 35° in the vertical. The increase in Gemini tilt for the second deployment was applied due to the presence of consistent returns from the seabed during Deployment 1. The Blueview was tilted down 5° relative to Deployment 1 to align with the Gemini. The sampling range of the Gemini was set to 50 m with an associated sampling rate of 10 to 11 Hz during Deployment 2, and the range for the Blueview set to 10 m.

Schematics of the sonar orientations are provided below, with the plan view shown in Figure 3 and profile views for the first and second deployments in Figures 4 and 5. Example sonograms for the Gemini and Blueview are provided in Figures 6 and 7.

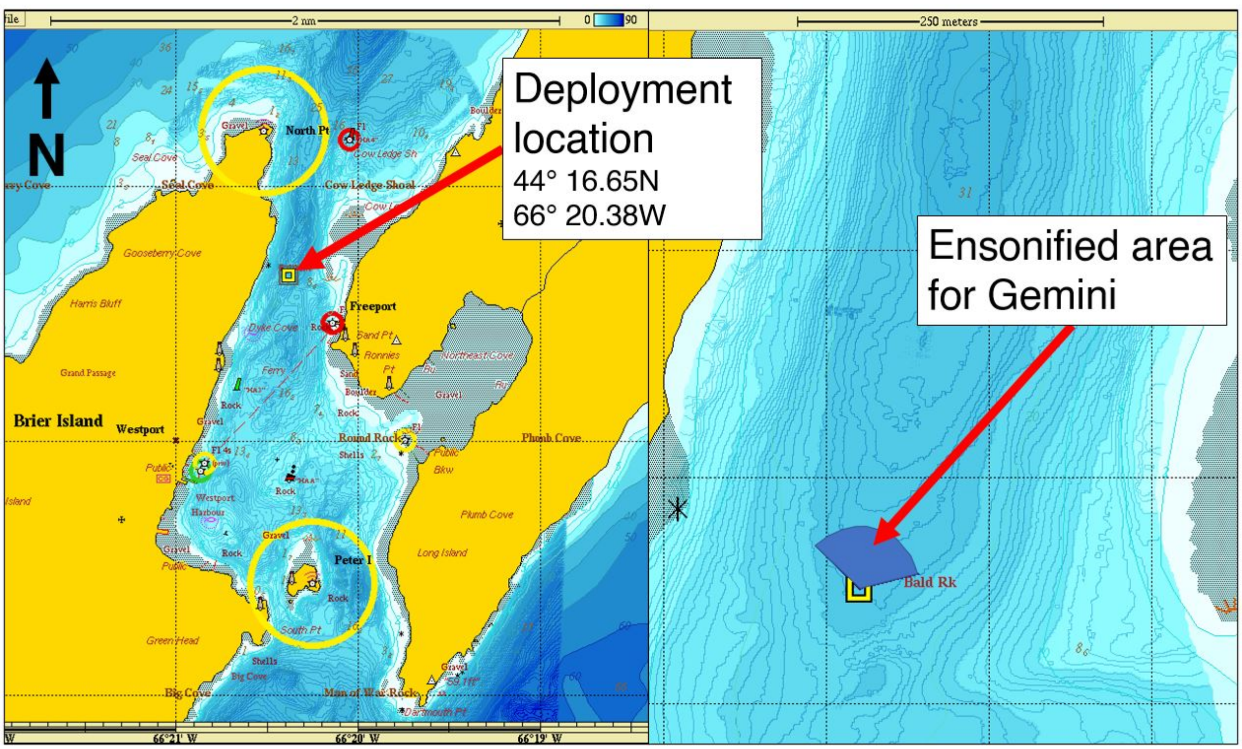

Figure 2: Deployment location

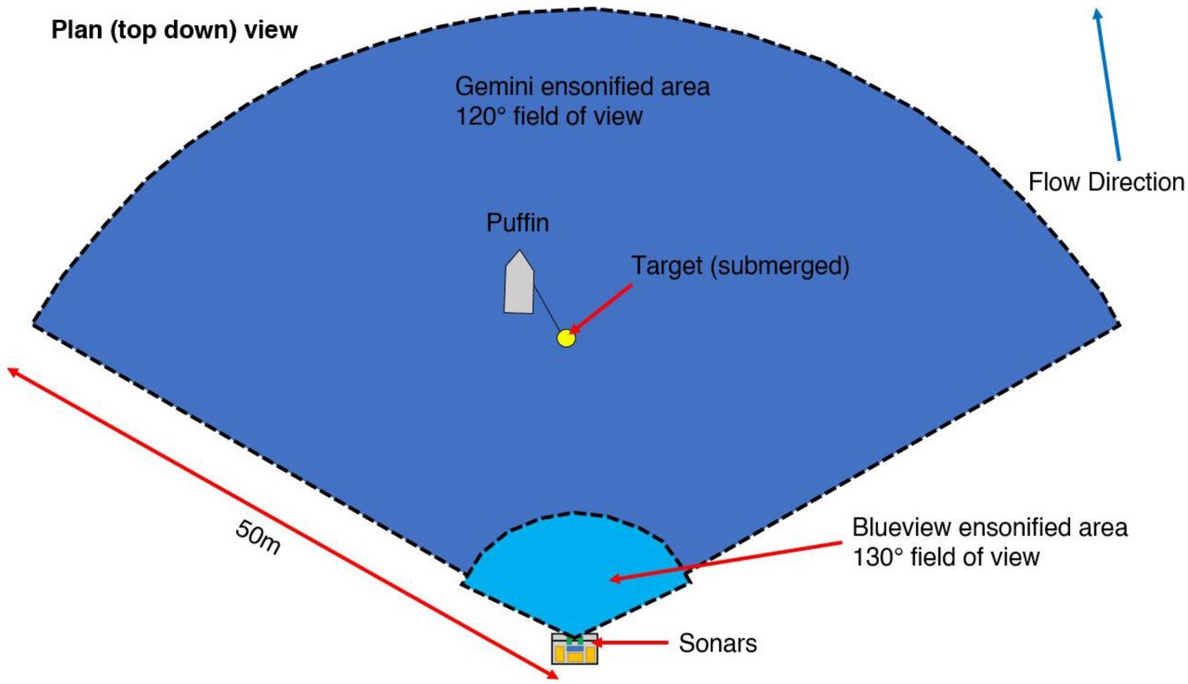

Figure 3: Experiment schematic - plan view

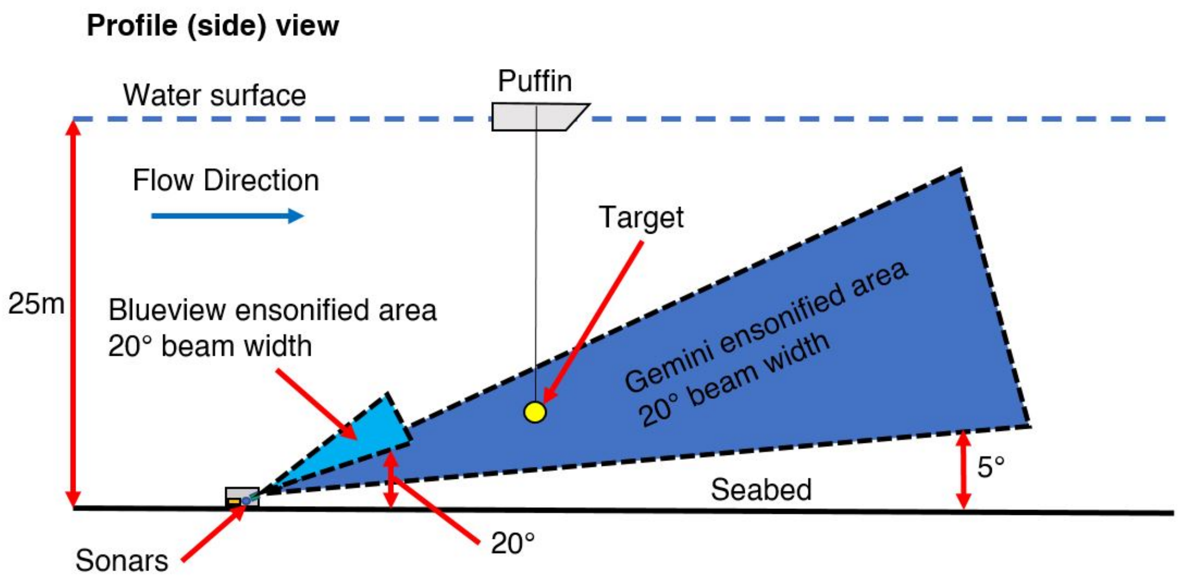

Figure 4: Experiment schematic - profile view - deployment 1

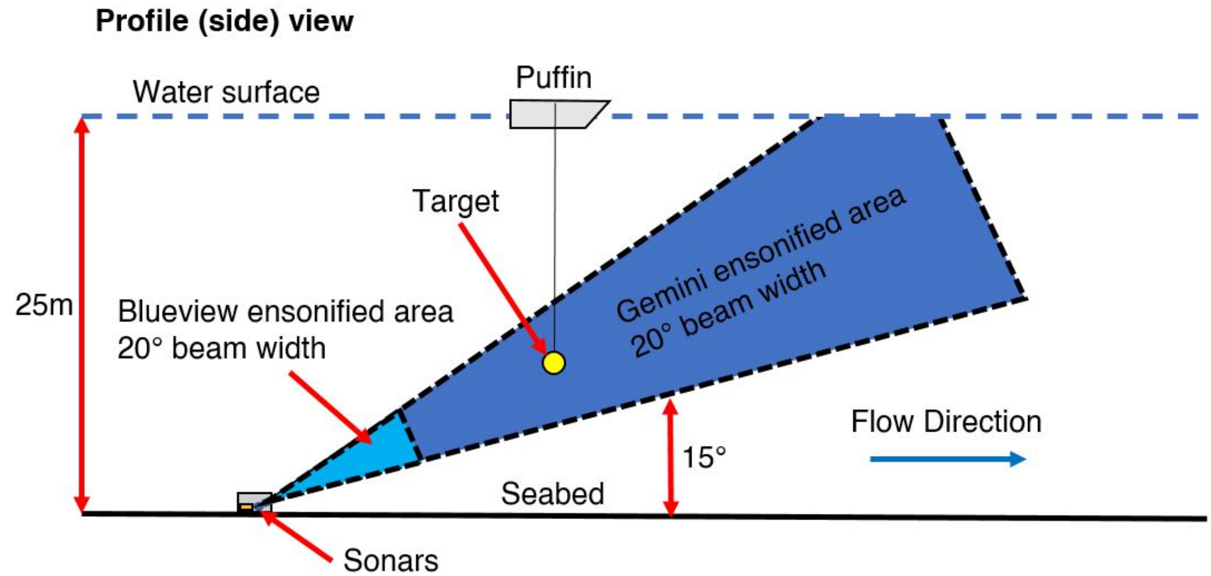

Figure 5: Experiment schematic - profile view - deployment 2

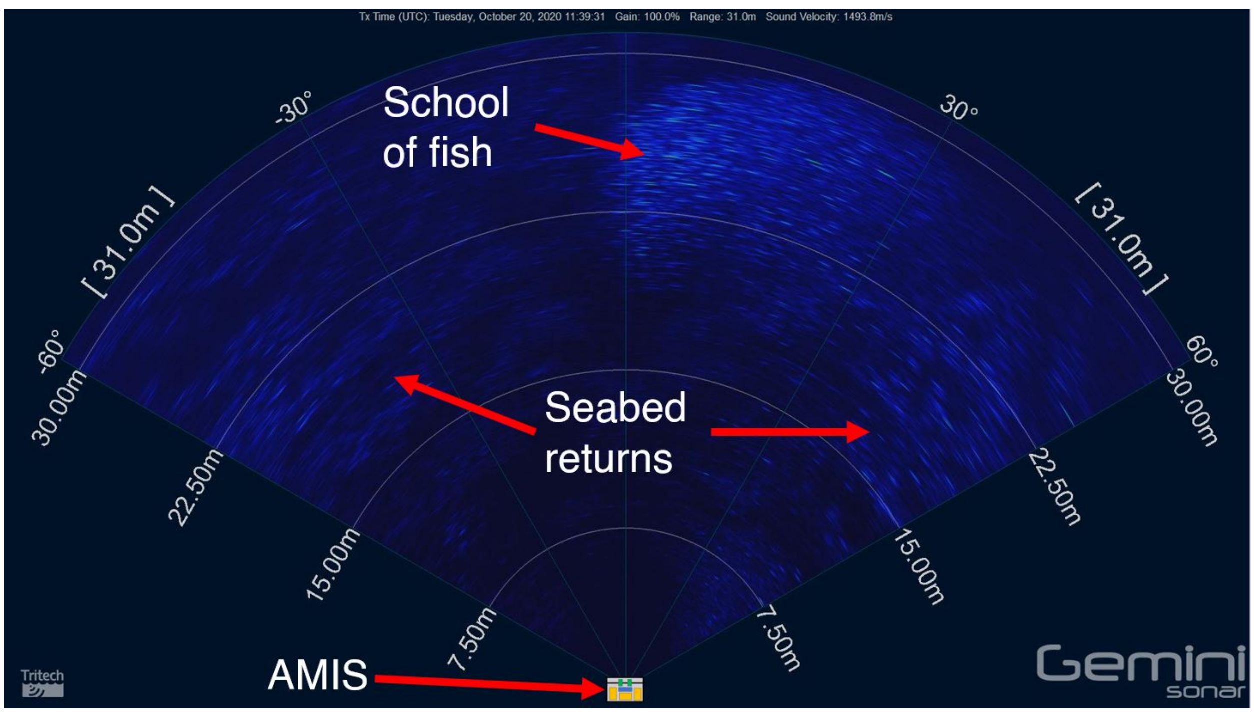

Figure 6: Example sonagram - Gemini first deployment

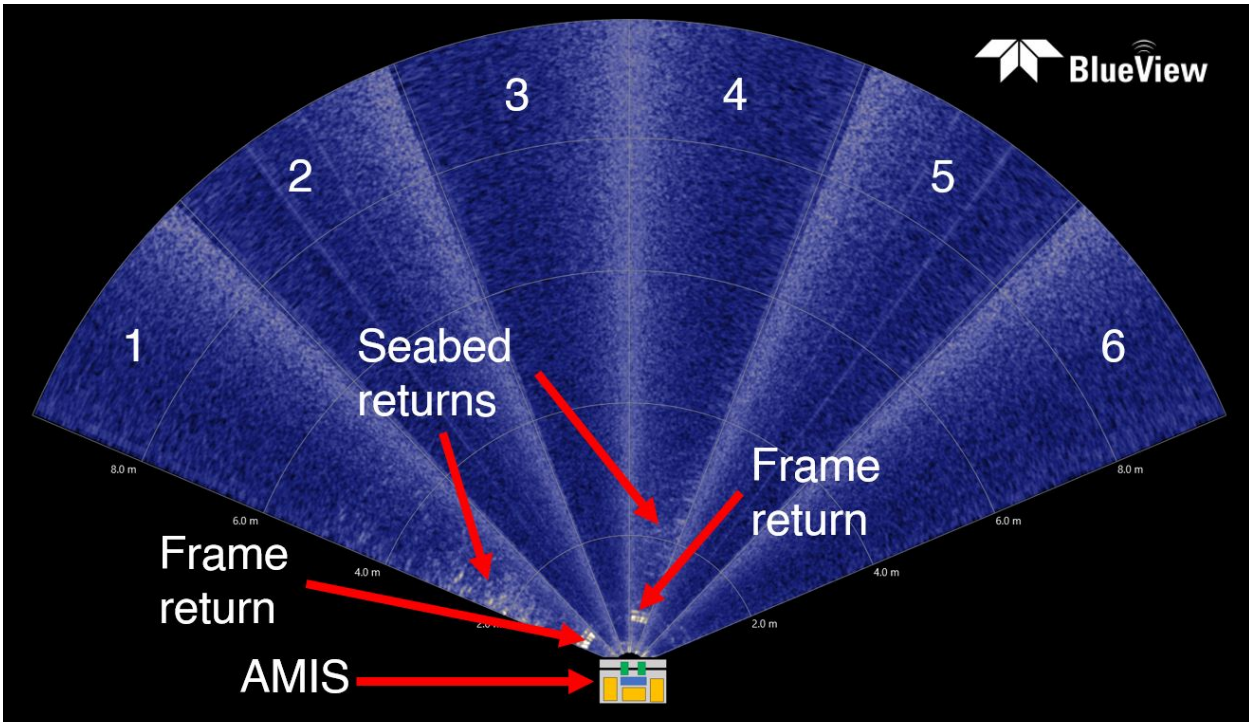

Figure 7: Example sonogram – Blueview second deployment

2.2: Data Collection

Three targets were used during data collection: a 0.45 kg (1 lb.) (9.5 cm long x 3.8 cm max diameter) lead fishing weight (Target 2), approx. 12 cm diameter basalt rock in a lobster bait bag (Target 3), and a V-Wing glider (Target 4) (approx. 52 cm wing tip to tip and 46 cm nose to tail) from Dartmouth Ocean Technologies (DOT). The V-Wing is designed to create downforce and maintain orientation in flow, with approximately (27 kg) 60 lbs. of downforce in 2.5 m/s flow. The target numbers were chosen to remain consistent with the convention used in vessel mount project (Trowse et al. 2020). The 1 inch diameter tungsten carbide sphere (Target 1 in the vessel mount project) was not included due to its acoustic similarity to Target 2 and the need to reduce the number of targets based on a relatively short data collection window.

Targets were suspended beneath research vessel Puffin (shown in Figure 8) while drifting through the study area. The Puffin repeatedly travelled to a position upstream from the sonars, then drifted with the tidal flow such that the drift trajectory allowed the targets to pass through the sonars' ensonified areas. The Puffin operated with its dual frequency Raymarine transducer (depth sounder and fish finder) turned off to avoid acoustic interference and collected flow measurements with a RDI 600 kHz ADCP periodically when changing between target types. The ADCP was out of the water during target deployments.

Targets 2, and 3 were suspended from the Puffin using a hand line spool with 200 pound test monofilament fishing line. Target 4 was suspended using 1/4 inch Polysteel fishing line due to the increased downward force, increased cost of the target (reducing risk of loss), and ease of handling. No metal was included in the target suspension system, knots were used to secure the targets with no hooks, shackles, etc. below the water line.

A series of 5 to 15 drifts were conducted for each target, with heights above the seabed that were consecutively increased at 3.6 m (2 fathom) intervals and with minor variations in the drift trajectory to the east and west of the AMIS deployment location. More drifts were conducted for Target 4 due to the higher level of control over depth and horizontal position relative to the Puffin. The AMIS system was fully autonomous, so no live view of data collection was available.

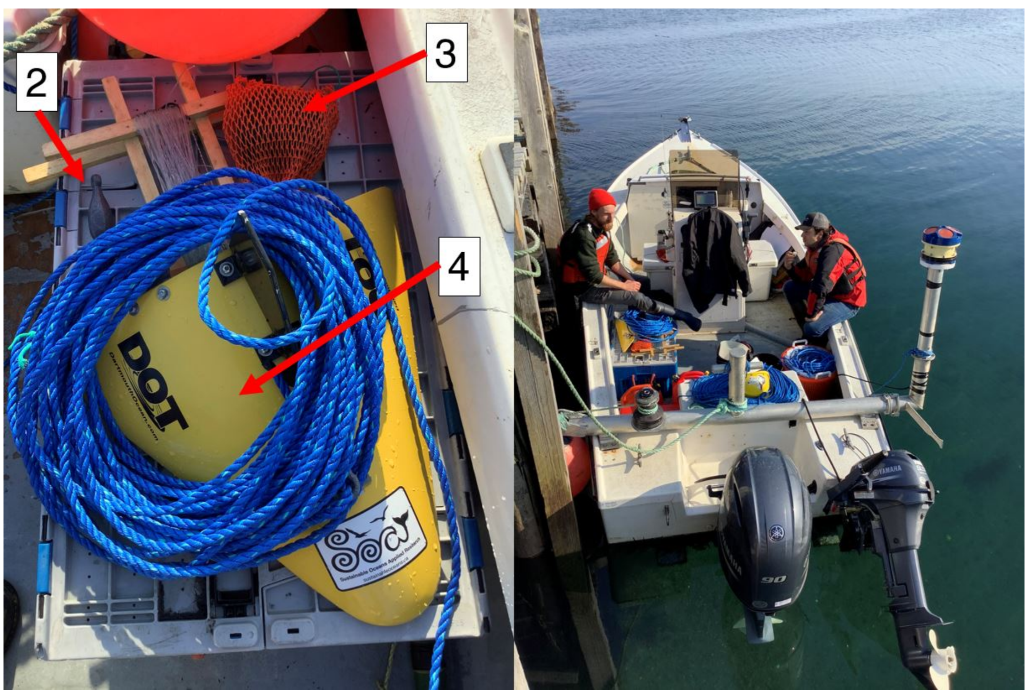

Figure 8: Targets and research vessel Puffin

2.2 Data analysis

The data collected in Grand Passage were manually analyzed to evaluate the performance of the Gemini and Blueview multibeam imaging sonars for detecting and tracking targets in strong tidal flow. The visualization and organization of the data were conducted using the proprietary software packages associated with each sonar: Gemini SeaTec and Teledyne ProViewer[1]. SOAR used these software packages for data review and organization by target type.

Consistent with the vessel mount project the sonar images were exported to video (1920 x 1080 resolution) to facilitate ease of sharing and consistency in the manual analysis. Video framerates were set to display data at 2x real-time speed. The ability to use increased payback speed was apparent from SOAR's initial analysis of the data files and utilized to demonstrate an increase in efficiency that may be applicable to active monitoring of tidal turbines.

Based on the results of Trowse et al. (2020), acoustic interference between the Gemini and the Blueview was expected. The signatures of acoustic interference for both instruments were consistent with those observed in the Trowse et al. vessel mount study.

2.2.1 Gemini

The video files from the Gemini were organized into training and test data sets, which were shared with 7 sonar observers who conducted the manual analysis, including participants from SOAR, Luna Sea Solutions, FORCE, Mi'kmaw Conservation Group, and MarineSitu. The training data set provides examples where each target is detected and tracked with a red circle indicating target position and a photograph from the optical camera identifying the target. The test data set included 41 data files where it was left to the observers to detect, track, and identify the targets.

[1] The development of automatic data processing algorithms for multibeam imaging sonars is an active area of research. Recent publications (e.g. Cotter and Polagye, 2020) on these methods have demonstrated the ability to detect and track targets with some ability to automatically classify between biologic and non-biologic classes. This classification level of processing typically relies on information from multiple instruments for co-registration of known targets (Joslin 2019). However, there is currently no software readily available with known ability to conduct reliable data analysis in turbulent flow with high levels of air entrainment. Therefore, data were analyzed manually to meet the primary objectives of the study.

A standard spreadsheet was provided to each observer including columns for:

- File number (for SOAR to cross-reference the data files)
- Target present (yes/no)
- Target identification
    - Type (1 through 4)
    - Certainty (1 low to 5 high)
- Detection range (minimum and maximum)
- Ability for detection and tracking (1 low to 5 high)
- Notes describing the trajectory of the target.

The results were categorized by target type and used to evaluate the performance of the Gemini including the effects of flow speed. The test data set included 3 files for Target 2, 9 files for Target 3, and 29 files for Target 4. The analysis was consistent with methodology for the vessel mount project, providing a quantitative comparison of performance for the Gemini sonar.

Links to the training and test data sets for are provided below. The data are best viewed in video form. As such, readers of this report are encouraged to watch these data videos for better understanding of the results and conclusions discussed in the following sections. A screen shot from the training data set is provided for each target in Figures 9 through 11.

Gemini training data	https://vimeo.com/483141927
Gemini test data with 50m range	https://vimeo.com/483142328

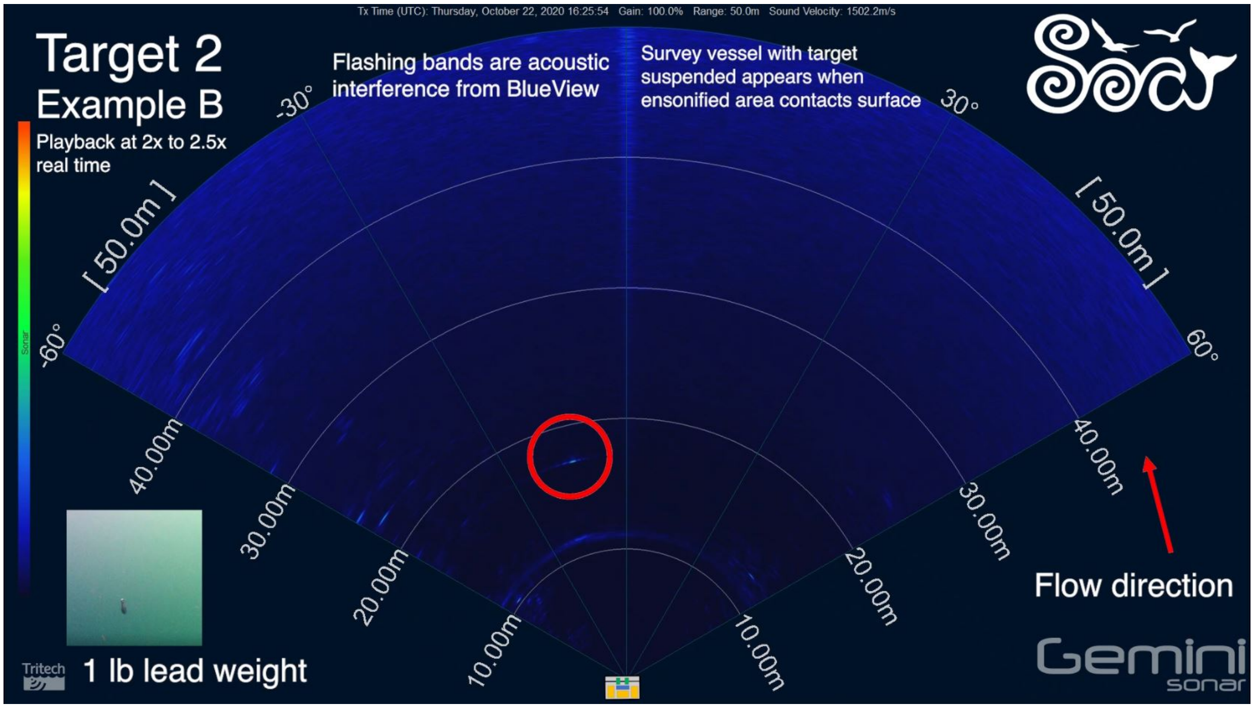

Figure 9: Example from training data - Gemini - Target 2

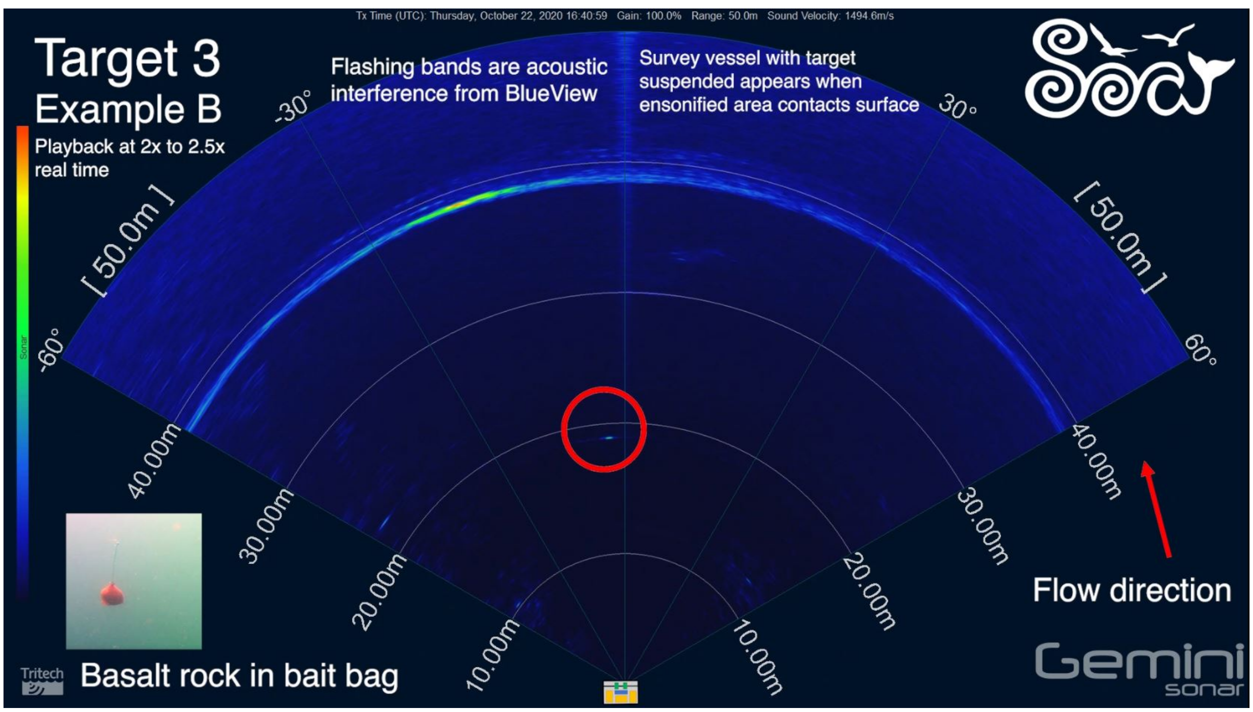

Figure 10: Example from training data - Gemini - Target 3

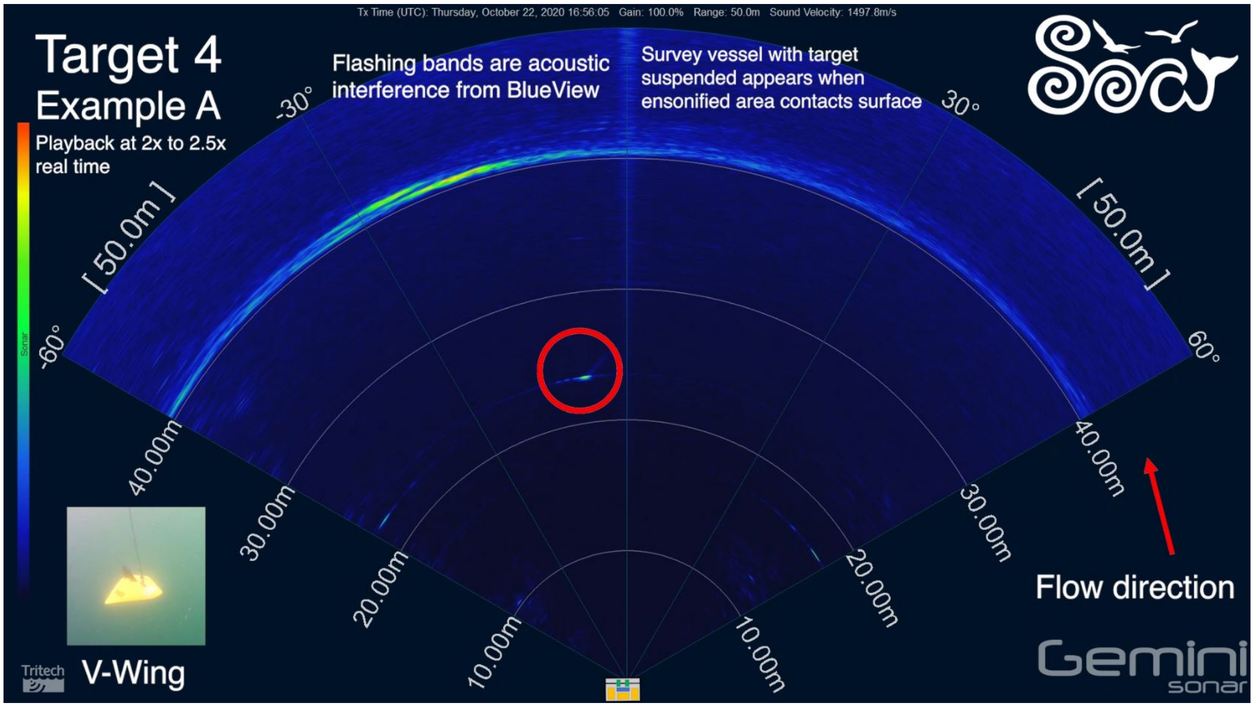

Figure 11: Example from training data - Gemini - Target 4

2.2.1 Blueview

Due to the small ensonified area of the Blueview, insufficient sightings of known targets were collected to generate training and test data sets. A manual analysis was conducted by SOAR, with a focus of events of concurrent detection by the Blueview and Gemini including natural targets (primarily fish) and occasionally the artificial targets used in our methodology. The data are discussed further in the Results section, including comparison of the two sonars.

3.0 Results and Discussion

3.1 Analysis of Gemini training and test data

A summary of results from the manual analysis of the Gemini test data is provided in Table 2, where observers' scores for target present (detected), target identified, max range tracked, and ability to detect and track targets were used to evaluate the performance of the sonar. Only data from Deployment 2 were used for consistent range (50 m) with the vessel mount project, with the comparison discussed in Section 3.4.

Table 2: Summary of results for Gemini, Deployment 2

Target type	Target present % correct	Target type % correct	Max range tracked % of set value	Ability to (1 to 5)	
				Detect	Track
Gemini (50m range)					
1					
2	95%	81%	74%	3.4	2.7
3	100%	43%	91%	4.3	3.8
4	100%	58%	99%	4.6	4.3
All	**99%**	**56%**	**95%**	**4.4**	**4.1**

The observers were able to reliably detect all targets in the majority (99%) of the test files, with tracking close to the 50 m range for Targets 3 and 4. Tracking range was reduced for Target 2, which is significantly smaller than targets 3 and 4. However, it is not clear whether the target tracks ended due to performance of the sonar or our ability to keep the 1 lb lead weight within the ensonified area. Conversely, the smaller size of Target 2, relative to Targets 3 and 4, aided in target identification, with 81% of the instances being correctly identified. Greater difficulty differentiating between Targets 3 and Target 4 is reflected by the lower target type percent correct scores.

The relationship between flow speed and sonar performance was evaluated by calculating the coefficient of determination, R^2, value between the flow speed and the detection and tracking scores. R^2 is a measure of the proportion of the variance in the dependent variable (detection and tracking scores) that can be predicted from the independent variable (flow speed). R^2 values range from 0 to 1, with 1 being one-to-one correlation. Flow speeds ranged from 1.4 to 2.4 m/s. The R^2 values for detection and tracking are 0.07 and 0.04, respectively, suggesting no significant relationship between flow speed and ability to detect and track the targets. A wider distribution of ability scores is apparent for the higher flow speed cases (see Figure 12). However, this may be a result of a larger number of samples at higher flow speeds as well as the distribution of target usage relative to flow speed.

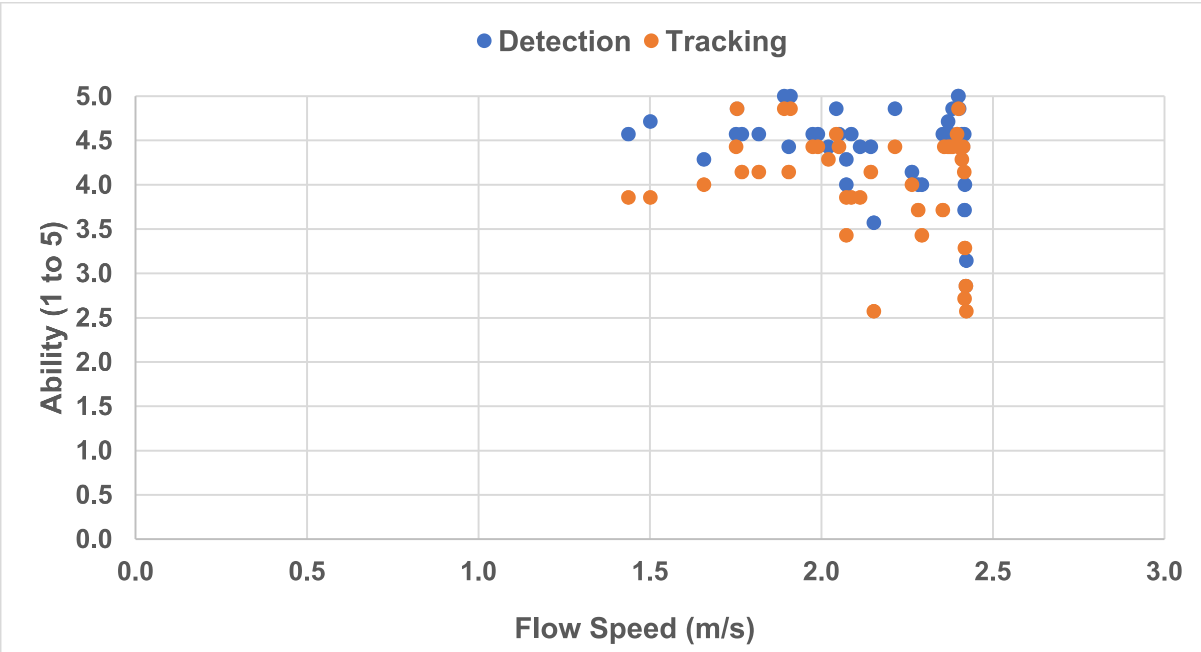

Figure 12: Effect of flow speed on Gemini target detection and tracking

3.2 Comparative analysis of Gemini and Blueview concurrent target detections

Data sets from both deployments were reviewed by SOAR to identify instances where natural targets (primarily fish) and occasionally the artificial targets used in our methodology could be identified in the data from both the Gemini and the Blueview. A link to a video file with 21 comparative cases is provided below, where cases 1 through 15 are from Deployment 1 and cases 16 through 20 are from Deployment 2. As with the training and test data analysis, the sonar data are best viewed in video form. Screen shots from cases 1, 4, 8, and 18 are also provided in Figures 13 through 16.

Concurrent Blueview and Gemini https://vimeo.com/487808248

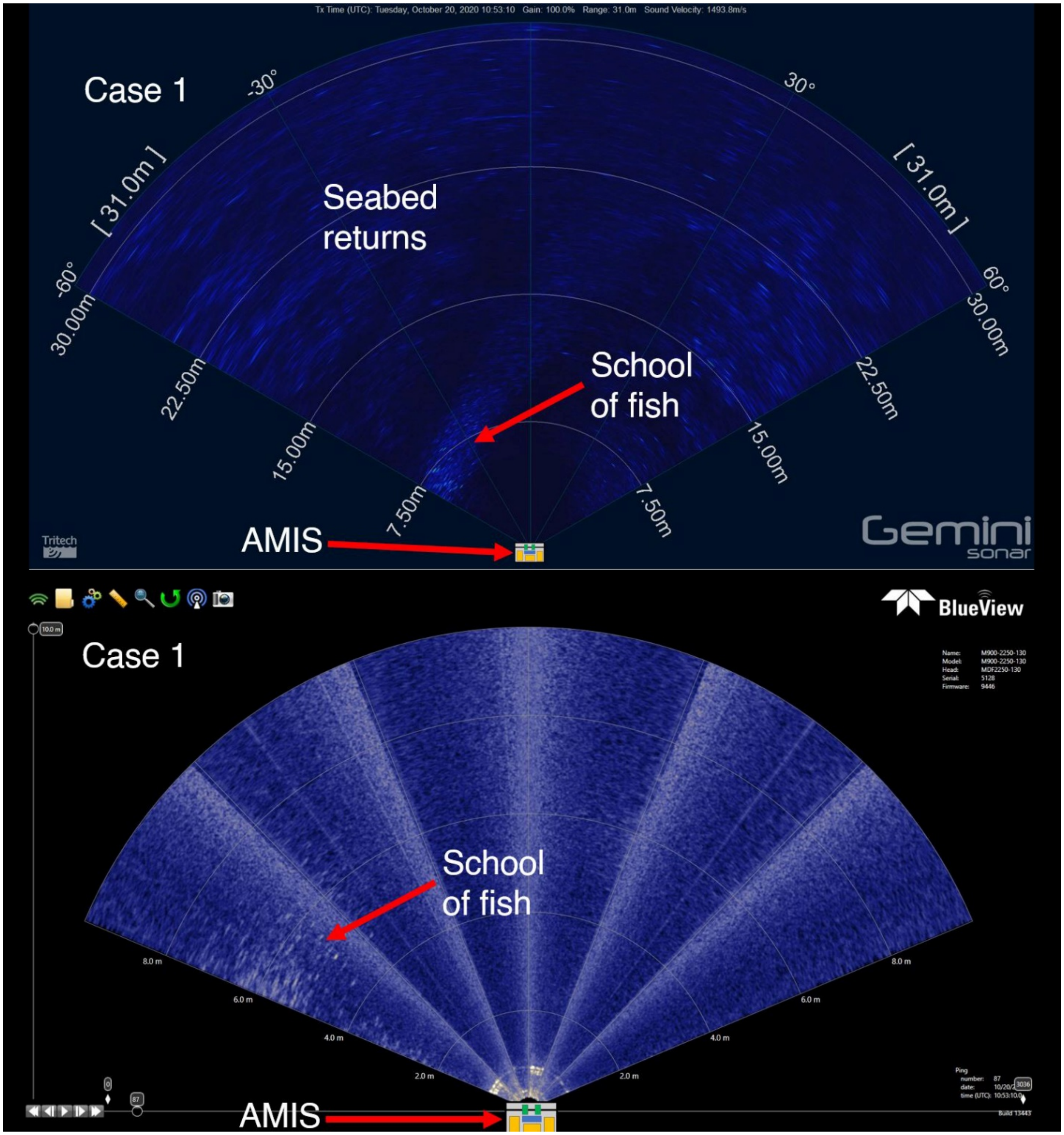

Figure 13: Concurrent Gemini and Blueview target detection - Case 1

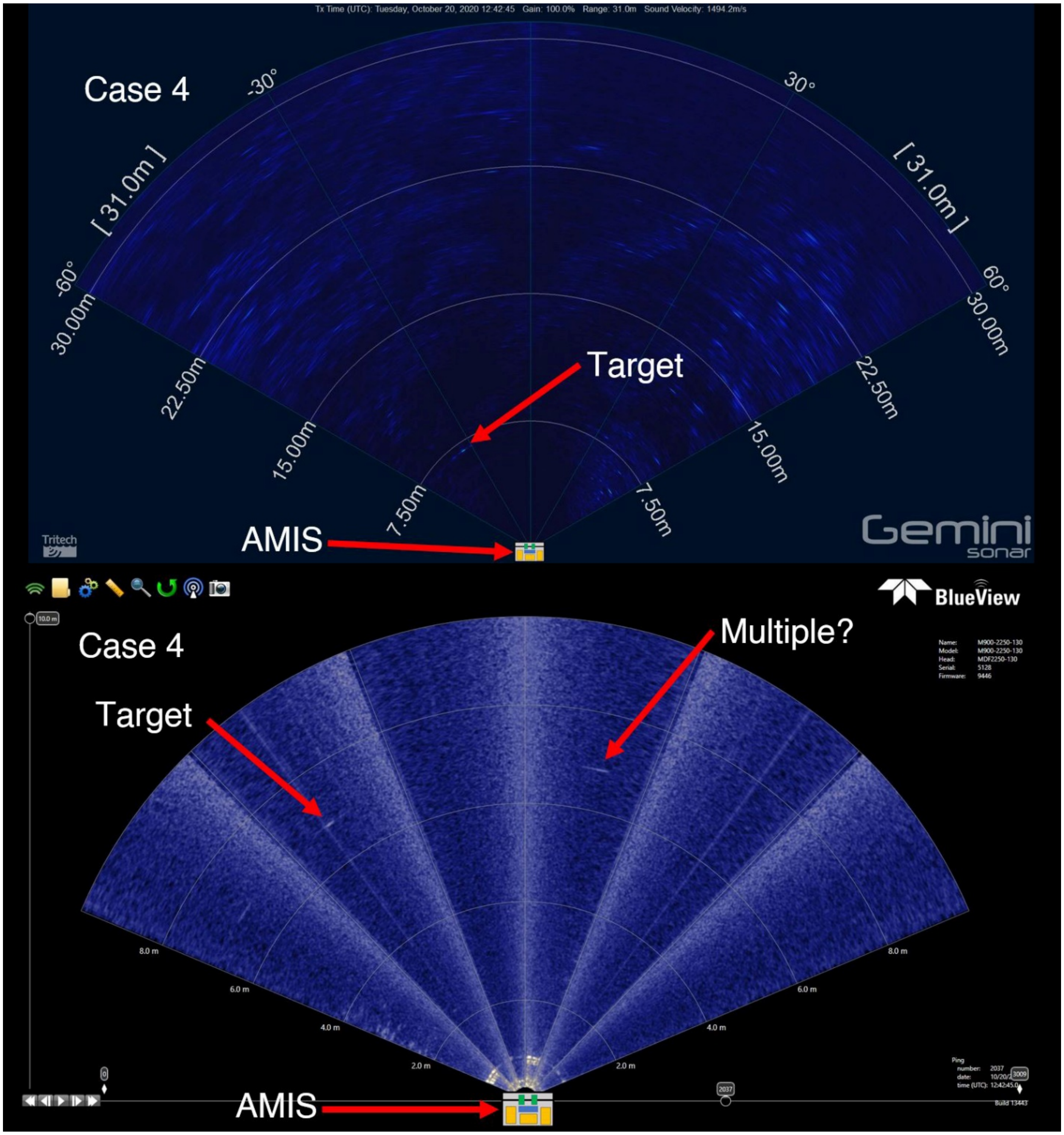

Figure 14: Concurrent Gemini and Blueview target detection - Case 4

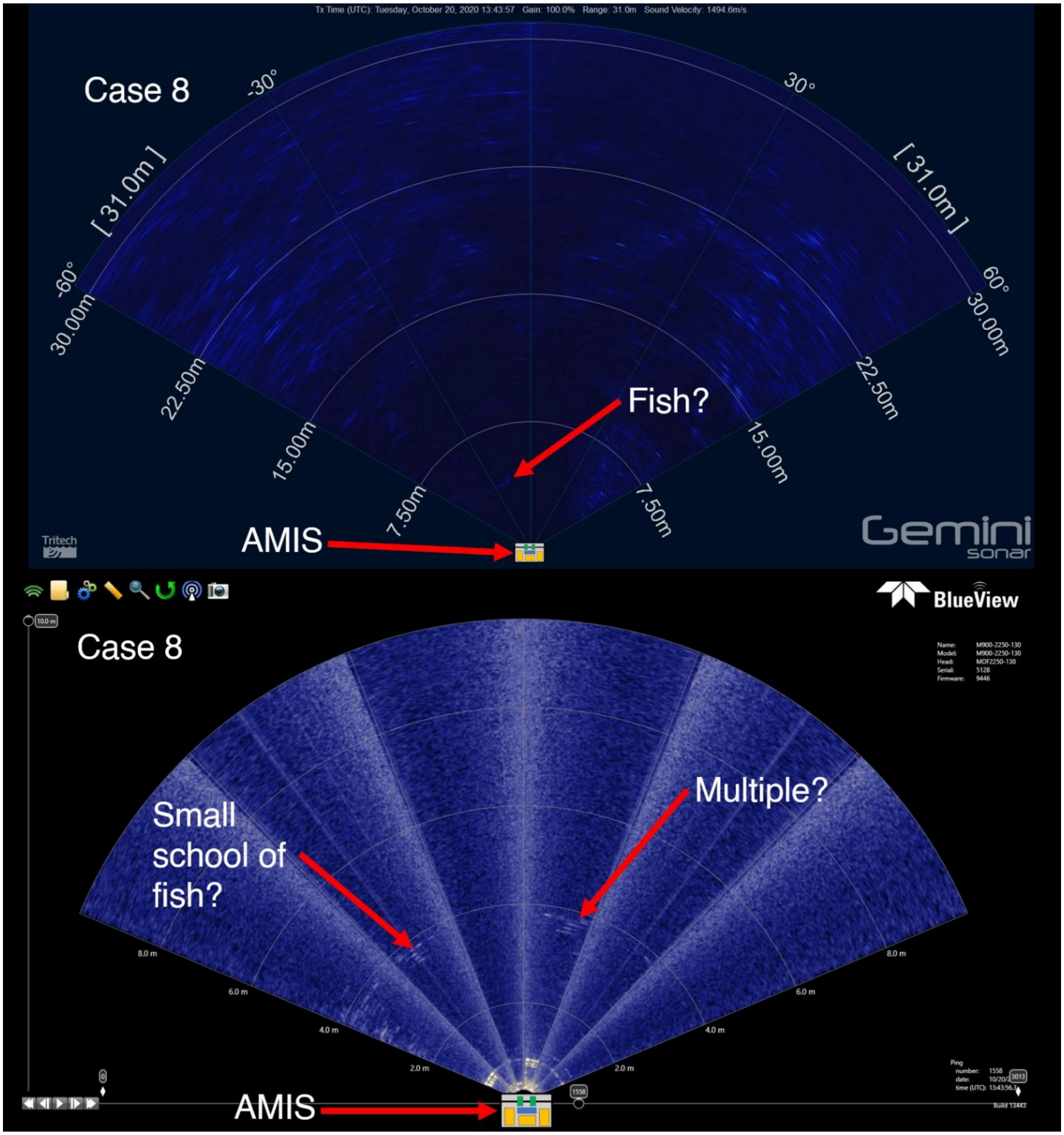

Figure 15: Concurrent Gemini and Blueview target detection - Case 8

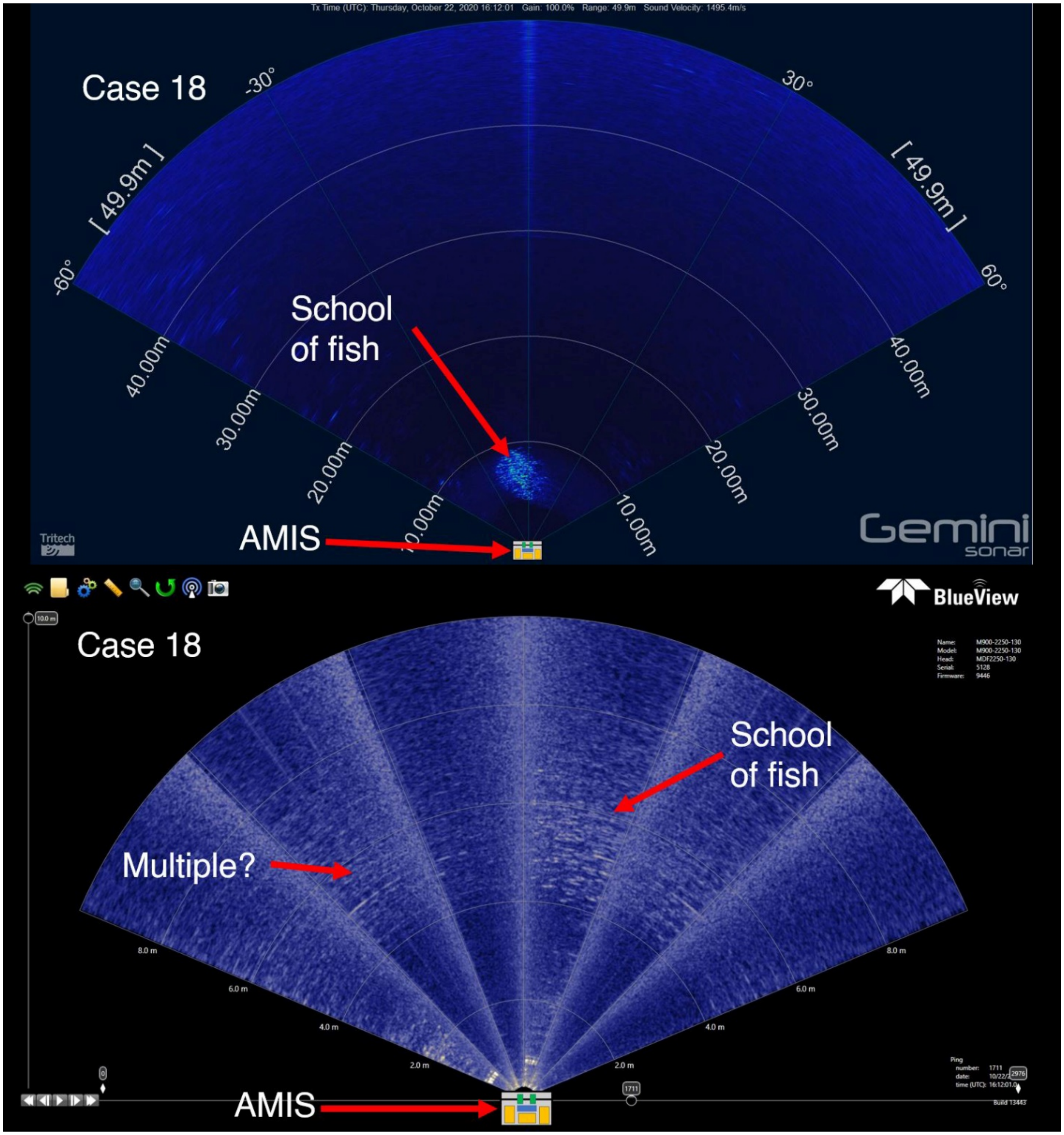

Figure 16: Concurrent Gemini and Blueview target detection - Case 18

Targets that were visible in the sonograms of both the Gemini and Blueview (up to 10 m range) were generally visible at larger ranges using the Gemini – often to its full sampling range of 30 m for Deployment 1 and 50 m for Deployment 2. For the first deployment with the ensonified area angled at 5 to 25° there were areas of seabed returns, but target identification and tracking were still possible due to the static nature of the seabed and continuous movement of the target.

When observing targets at close range, the Blueview demonstrated ability to provide the additional resolution expected of a higher frequency system. For example, in case 8, shown in Figure 15, individual fish in a small school are clearly identifiable. Fish in close proximity (< 2 m) to AMIS were well resolved by the Blueview. Though identifying discrete targets (i.e., individual fish in a school) was also possible with the Gemini at close range, it was subject to limitations associated with sampling frequency (range dependent), wavelength of the transmitted ping (720 kHz), and resolution of the sonogram (pixels/m).

3.3 Hardware limitations

The MKI model of the Blueview M900-2250 suffers from hardware limitations, one of which manifested in this study as multiple high-noise bands at fixed angular coordinates in the sonograms (see the lighter-coloured boundaries between numbered sectors in the Blueview sonogram shown in Figure 7). Targets generally could not be identified when they coincided with the bands, as the backscattered target signals were of comparable magnitude to the background noise level. This is consistent with observations made during the Trowse et al. (2020) vessel mount project.

SOAR contacted Teledyne technical support for further information, and were informed that Teledyne have released a second version (MKII) of the M900-2250, which mitigates this issue at the expense of a narrower swath width (reduced to from 130 to 45°). Further information is provided in the report for the vessel mounted project.

Some phenomena observed in the Blueview data suggest a transducer alignment issue. As noted in the Methodology section, despite the upward tilt of the Blueview at angles of 20° to 40° from the horizontal plane of the AMIS frame (Deployment 1) and 15° to 35° (Deployment 2), the frame and seabed are visible in sectors 1 and 4 of the sonogram. The lack of an acoustic shadow suggests that the frame and bottom returns are from sidelobes rather than the main acoustic beam. A potential transducer misalignment could explain target disappearance observed during data collection and analysis for the vessel mount project, where target tracks were regularly lost when travelling from the area occupied by one sector to the adjacent one. In some cases the Blueview sonograms show multiple returns from targets, as shown in Figures 14 through 16, that are not visible on the Gemini. If an artifact of a hardware issue it could result in uncertainty in target position, especially relevant in application to monitoring near-field interactions between marine animals and tidal turbines. Note that we have not yet contacted Teledyne regarding these issues.

3.4 Comparison to vessel mounted multibeam sonars

A comparison of the observers' scores for the bottom and vessel mounted Gemini cases is provided in Table 3. The vessel mount data (see Trowse et al. 2020) were analysed using the same methodology outlined in this report: that is, manual review by sonar observers using training and test data sets. For the vessel mount data, the values for "All" are increased from those in Trowse et al. 2020 due to the exclusion of Target 1 (1 inch tungsten carbine sphere) from the calculation. Target 1 was the smallest of the four targets and was characterized by the lowest scores.

Table 3: Comparison of results from bottom and vessel mounted Gemini

Target type	Target present % correct	Target type % correct	Max range tracked % of set value	Ability to (1 to 5)	
				Detect	Track
Gemini Bottom Mount					
2	95%	81%	74%	3.4	2.7
3	100%	43%	91%	4.3	3.8
4	100%	58%	99%	4.6	4.3
All	**99%**	**56%**	**95%**	**4.4**	**4.1**
Gemini Vessel Mount					
2	95%	23%	81%	3.4	3.1
3	96%	33%	92%	4.1	3.9
4	100%	79%	100%	4.5	4.5
All	**97%**	**46%**	**91%**	**4.0**	**3.9**
Bottom - Vessel Mount Scores					
2	0%	58%	-7%	0.0	-0.4
3	4%	10%	0%	0.2	-0.1
4	0%	-22%	-1%	0.1	-0.2
All	2%	10%	4%	0.4	0.2

The target-averaged scores for the bottom mount data set are slightly higher in all categories relative to the vessel mount data. We had substantially greater control of target positioning during the vessel mount data collection. We were able to start tracks closer to the sonars and hold targets at a constant range. This provided observers more time to detect and identify the targets at close range. Despite this, the greater bottom mount scores may not be surprising given the reduction in data contamination by wave and wake-related entrained air.

Proximity to the sonars likely increased the observers' ability to correctly identify Target 4 from the vessel mounted sonar. The characteristic shape of Target 4 was easily recognizable when viewed at close range (i.e., within ca. 20 m), but it exhibited acoustic returns that were less easily differentiated from Target 3 at larger ranges. The omission of Target 1 from the bottom mount experiment led to Target 2 being easier to distinguish (no confusion between similar targets) and is likely the reason for greater success compared to the vessel mount case. The reduced ability to identify Target 4 in the bottom mount data is most likely related to the reduced amount of time it was present in close range to the sonars.

4.0 Conclusions

The project addressed the objective of assessing the performance of bottom deployed multibeam imaging sonars for target detections, including the extent of signal interference from waves/turbulence, and entrained air.

The Tritech Gemini 720is received high scores from the observers in the ability to identify the presence of, visually detect, and track targets in videos displaying sonogram data output. The observers correctly identified the presence of a target in 99% of cases, and gave average scores greater than 4 out of 5 describing their visual detection and tracking ability. Targets were correctly identified roughly 50% of the time.

The results indicate a slight increase in visual detection and tracking ability relative to similar data collected from a vessel mounted orientation, and a net decrease in ability to correctly identify targets. We attribute the apparent increase in efficacy in the bottom mount case to the reduced presence of entrained air from waves and vessel wake in the sonar's ensonified areas. The reduction in percentage of correctly identified targets in the bottom mount case may be attributable to the increased ranges between target and sonar, as well as faster movement of the targets through the ensonified area. In general, the range to the target within the Gemini's detection area appears to play an important role in the ability to resolve and identify targets with diameters between ca. 5 and 50 cm.

For the bottom mount experiment, we were drifting guided by the currents and the AMIS deployment location, and were highly successful in getting detectable, identifiable, and trackable targets into the Gemini's ensonified area. Due to the smaller area ensonified by the Blueview, we had difficulty getting targets into the field of view. The limited number of target sightings precluded our use of the planned training and test video methodology. SOAR instead conducted a comparative analysis for which targets of opportunity (e.g., fish) were detected in the fields of view of both sonars. The Blueview demonstrated ability to resolve close-range (less than 10 m) targets. However, the use of the Blueview data was limited by the same hardware issues described by Trowse et al. (2020), and in the Hardware Limitations section of this report.

The Teledyne Blueview M900-2250 MKI is an impressive technology that offered the ability to resolve finer scale features of the targets and their movements in some cases. However, the persistent high-noise bands resulting from a known hardware issue and an apparent transducer alignment issue (discussed in Section 3.3) represented substantial impediments to reliable target detection and tracking. We conclude that data from the Blueview did not add substantial value or insight to the target analysis when used in conjunction with the Gemini. This should not rule out potential use of other MHz frequency multibeam sonars for monitoring the 10 m range in a combined sonar approach, including MKII of the Blueview.

SOAR recommends use of the Tritech Gemini 720is for application to monitoring interactions between marine animals and tidal turbines. It is likely that this technology will contribute significantly to effective monitoring and advancing knowledge of importance to regulators and other stakeholders. The Gemini demonstrated a high level of utility for detecting and tracking targets from vessel and bottom mounted orientations in tidal flows up to approximately 2.5 m/s, which is near to the maximum flow speed at Grand Passage. The Minas Passage is known to have higher flow speeds, which may result in higher levels of air entrainment. For comparison to the Minas Passage a flow speed exceedance curve is provided in Figure 18 calculated using depth averaged ADCP measured flow speeds from FORCE Berth Site A (45.3649 -64.4308). It shows maximum flow speeds of approximately 4.5 m/s and 2.5 m/s to be exceeded approximately 36% of the time, or conversely, flow speeds to be less than 2.5 m/s 64% of the time.

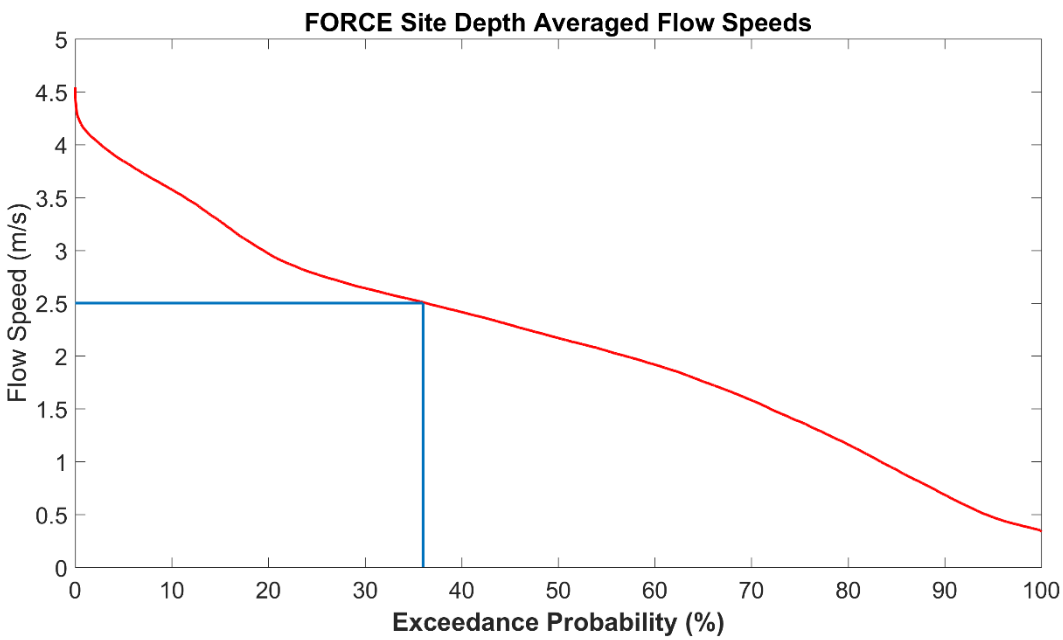

Figure 17: FORCE Site flow speed exceedance curve

Data analysis was successful for manual observers viewing data played back at 2x real time speed. Future work should consider efficiencies associated with accelerated data playback and could support use of software with variable speed playback that also allows for time and space encoded notes.

For planning future data collection careful consideration of sonar orientation is critical. In an oceanographic context, the ensonified areas are relatively small and are sensitive to returns from seabed and sea surface. Careful planning of the ensonified area is required based on the questions to be addressed by the monitoring while minimizing unwanted returns. The ability to adjust orientation is highly beneficial.

With respect to deploying multibeam sonars from the surface (i.e., vessel) or seabed, the sonars performed well from both positions, despite increased levels of air entrainment in the vessel mount case. The selection of deployment position for monitoring tidal turbines is likely to be defined by the nature of the tidal device (floating or seabed mounted) and the questions to be addressed by the monitoring.

Some level of acoustic interference from other active sonar systems must be expected when carrying out deployments in or near active ports or passages, whether from passing pleasure or commercial craft, or from other marine operations. Data analysis methods and systems should be designed with this in mind, treating acoustic interference as an element to be anticipated and mitigated where possible through software processing.

Manufactured targets were the focus of this experiment, but marine animal targets were also observed in abundance in Grand Passage. Data were collected that show the multibeam sonars to perform well in detection and tracking of fish and other targets of opportunity. These data require additional analysis, but some preliminary images are available. This connects with the secondary expected outcome of the project, providing data sets to support further research beyond the scope and timeline of this project.

Further testing of bottom mounted multibeam sonars would be useful in four focus areas, including:

1) fish and other marine animals in locations and seasons (times) with high levels of animal abundance and variety,
2) evaluating most effective sonar orientations for monitoring the near field of tidal turbines,
3) flow speeds that exceed 3 m/s, and
4) increasing efficiency in data assessment, possibly including reliable automation.

This work should build upon success in Grand Passage to conduct next steps in stronger flows present in Petit Passage and Minas Passage.

The report titled "Field Assessment of Multi-beam Sonar Performance in Surface Mount Deployments" (Trowse et al. 2020) provides similar analysis for the case of surface mounted Gemini 720is and Blueview M900-2250.

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