Appendix VIII

Active sonar environmental monitoring for Fundy tidal energy project

COVE

TECHNICAL SERIES

ACTIVE SONAR ENVIRONMENTAL MONITORING FOR FUNDY TIDAL ENERGY PROJECT

A Panel Discussion by Subject Matter Experts

Spring 2019

Centre for Ocean Ventures and Entrepreneurship
27 Parker St., Dartmouth, NS, B2Y 4T5

Centre for Ocean Ventures and Entrepreneurship (COVE)

The Centre for Ocean Ventures and Entrepreneurship (COVE) is an ocean tech business hub that encourages collaboration across sectors to connect local, national and international companies in the ocean industry. We are a catalyst in creating the world's next commercial and revolutionary ocean tech advances by bringing together people, ideas, industry and research.

Strategically located on the Halifax Harbour, more than 55 companies are located at COVE, ranging from small ocean technology start-ups to large companies. The companies are focused on all sectors of the ocean economy – transportation, energy, the capture fishery & aquaculture, marine tourism, and defence & security. The programs, facilities and services offered through COVE bring the ocean technology cluster together to advance the competitive position of members in the global ocean industry.

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Foreword

The COVE Technical Series investigates and advances ocean technology challenges that potentially hold market value and are of interest to COVE tenants, stakeholders and ocean industry as a whole. This study, ***Active Sonar Environmental Monitoring for Fundy Tidal Energy: A Panel Discussion by Subject Matter Experts***, provides input on the current and near-future capability of active acoustic instrumentation, devices, and techniques for environmental monitoring in highly turbulent marine environments.

The support of the Ocean Technology Council of Nova Scotia (OTCNS) www.otcns.ca and the provincial and federal governments for this event and related activity is acknowledged. Irving Shipbuilding Inc. is a foundational contributing sponsor to COVE's programming and to IORE, the Institute for Ocean Research Enterprise.

This work was undertaken and its report prepared by Dr. Paul Hines of Hines Ocean S&T to whom we are grateful. He may be contacted as below:

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Introduction

The **Centre for Ocean Ventures and Entrepreneurship (**COVE) held a round-table discussion on active sonar technology and its underlying science with a select group of subject matter experts, on May 23rd 2019. This is in line with COVE's mandate to bring together people across ocean-industry sectors and research areas to identify and tackle ocean technology challenges with market potential. This round-table was a contribution to a broader set of projects related to environmental monitoring being planned within 'The Pathway'—a new initiative by the Offshore Energy Research Association of Nova Scotia (**OERA**) and The Fundy Ocean Research Center for Energy (**FORCE**). The goal of the meeting was to provide input on the current and near-future capability of active acoustic instrumentation, devices, and techniques for environmental monitoring in highly turbulent marine environments.

Problem statement: Tidal power is recognized as a clean, renewable source of energy. However, environmental monitoring of these systems can pose unique challenges. Underwater acoustic devices are a primary tool for monitoring fish and marine mammals. However, in environments such as the Bay of Fundy, the utility of these devices is severely restricted due to the high tidal flow-rates, and the subsequent eddies, whirlpools and vortices that entrain air bubbles well below the surface. Previous studies have shown that the high ambient background noise in this turbulent flow severely limits the utility of passive acoustic monitoring devices. Active sonar is a potential option but the entrained air interferes with transmission of active sonar signals, *and* causes high reverberation against which to detect the target echoes.

Objective: The goal of the round-table was to convene a panel of experts in active sonar technology *and its underlying science*, to discuss the limitations of existing technologies in these environments. Also under consideration, is whether these limits are imposed by the physics of the environment, or are simply artifacts of current active sonar technologies, which have not been optimized for these specific conditions.

Outcomes: The discussion is captured in this summary report and identifies the key points of the meeting and specific science and technology (S&T) questions that should be addressed to reach the stated objective. The goal is to have this report distributed to the attendees and stakeholders within a few weeks of the meeting. Moreover, the S&T questions that are identified herein may be used to guide the direction of funded research projects which are forthcoming as part of 'The Pathway' program.

Following this introduction, the meeting participants are identified and a summary of the panel discussion is presented. Post meeting comments provided by some of the subject matter experts (SME) are contained in Appendix A at the end of this report.

MEETING LOGISTICS AND OVERVIEW

The meeting was conducted at the COVE North Building, 4th floor conference room B. Video conferencing allowed remote attendees to "see and be seen" and contributed to their high level of engagement in the discussions. Table I lists the SMEs invited to the panel discussion as well as the other attendees and their primary roles. Entries in grey note SMEs who were unable to attend. Names followed by "R" were remote attendees.

Table I: Subject Matter Experts and other attendees to the panel meeting.

Name	Affiliation	Subject Matter Expertise (partial)
David Barclay	Dalhousie	TL modelling, ambient noise
Alex Hay	Dalhousie	Ocean acoustics, remote measurement of turbulence in tidal channels
Bruce Armstrong	GeoSpectrum	Transducer design
Sara Stout-Grandy	Vemco	Fish tagging and tracking
Craig Brown	NSCC	Ocean mapping, remote sensing, env. monitoring
Chris Loadman	TR	Sonar receiver design, signal processing
Jinshan Xu	DFO	General acoustics, physical oceanography, fish acoustics
Ian Church	UNB	Ocean mapping, hydrodynamic modelling
Olivier Beslin	UEMS	Turbulent Boundary Layer, towed arrays
Brendan Harvey	UEMS	DCL, towed arrays, sonar
Joe Hood	GeoSpectrum	PD-PFA, DCL
Ron Kessel, **R**	SAL	TL modelling, HF sonar, high-res sonar
Tom Weber, **R**	UNH	Fish sonar, bubble scattering
Andone Lavery, **R**	WHOI	AUV navigation in turbulent rivers
John Horne, **R**	UW-SAFS	HF sonar for fish monitoring
Name	**Affiliation**	**Role**
Paul Hines	HOST	Moderator/Chair
Dan Hasselman	FORCE	Supporting Context/Co-chair
Tyler Boucher	FORCE	Supporting Context
Tony Wright	FORCE	Observer
Alisdair McLean	OERA	Observer/Stakeholder
Luiz Faria	OERA	Observer/Stakeholder
Shawna Eason	NSDOE	Observer/Stakeholder
Leslie Munro	COVE	Meeting support
Cal Murphy	COVE	Meeting support
Kylee Weir	COVE	Meeting support

A simple agenda (shown in Table II) was distributed prior to the meeting to provide some general guidance to the discussion and ensure time was spread over several topics of interest. The agenda was accompanied with the six questions show below. These questions were used to motivate discussion; however, the discussion was not limited to addressing these questions.

Q1. Are existing linear acoustic models sufficiently accurate for this environment (small amplitude, and more importantly, no rotational flow, i.e. Curl= 0).?

Q2. Does entrained air represent a physical limit or can we design systems around it?

Q3. Are active sonars at their functional limits, or are they just poorly matched to work in turbulent flow?

Q4. Will we get more traction from increasing Signal, or decreasing Noise?

Q5. Will we get more traction from improving hardware (sensors) or improving software (DCL?)

Q6. What should we be measuring/modelling *right now* to fast track progress in this topic?

Table II: Proposed meeting agenda.

Time (ADT)	Event	Name	Comments
11:30-12:15	Lunch	Local Participants	
12:15	Assemble	All	
12:30	Opening remarks	Hines, Hasselman	Review problem statement and context
12:40	Panel Introductions	Hines	Introduction of relevant expertise of participants
13:00-16:00	**Moderated Panel Discussion**		
13:00	Part 1: Challenges of the Physical Environment		
13:45	Part 2: Technology Solutions: Current Capability and Ongoing Development		
14:30	Part 3: The Key S&T Questions (Experiment and Theory)		
15:30	Part 4: Wrap Up		

Discussion Summary

The SME's represent a broad range of expertise necessary to tackle the very challenging objective laid out in the introduction. The round table meeting was an active and engaging technical discussion with all participants contributing clearly articulated, deep technical insights throughout the three and one-half hour exchange.

Following opening remarks from the moderator and a short welcome from Mr. Alisdair McLean of OERA the technical exchange began. First, a short presentation on the technical challenge was provided by Dr. Daniel J. Hasselman. This reinforced the problem statement identified in the introduction. The environmental monitoring program includes hydroacoustic fish surveys done using transects across the test site and across the bay using an EK80 split beam echosounder to do a 24-hour survey (2 ebb/flood cycle). The video output from Echoview contains a substantial amount of backscatter noise from the entrained air bubbles and sediment throughout much of the water column. Separating the signal (fish echoes) from the noise (scatter from bubbles and sediment) is the primary challenge.

The discussion began by considering whether linear acoustic models are sufficiently accurate for this environment. David Barclay responded that although there may be some flow-related effects, he felt the linear acoustic models in place were adequate to tackle the problem. Scatter from bubbles was the real issue. The SMEs agreed with this observation.

Ron Kessel made a clear distinction between turbulence and entrained sediment and bubbles. Turbulence will not generate scatter; its only relevance is that it entrains sediment and air bubbles which cause scatter. (Moderator note: Turbulence will also raise the ambient noise background which may or may not be the limiting factor in active sonar. In the present case however, volume reverberation from the bubbles is likely the limiting factor.) He suggested that the best way to monitor fish in the immediate vicinity of a turbine (20 m to 50 m) is to reduce bubble noise. High-resolution multi-beam imaging sonars might be considered (e.g., BlueView P450, RESON Seabat 7128, and possibly the much shorter range and much higher-frequency DIDSON sonar). High resolution imaging sonars:

1. dramatically decrease the volume V for bubble backscatter (smaller region of interest and the very narrow beamwidths of multibeam imaging sonars (0.5 to 1.5 degrees). It is expected that bubbles will not be a problem, but this is must be tested *in situ*.

2. give nearly visual-quality scene-rendering with fish evident (presumably restrictions on fish body and schools size apply), with the immediate understanding and impact that visual scenes have for non-experts concerned about impact on fish.

3. should be positioned with the sonar line of sight perpendicular to fish-path into turbine, to maximize the target strength (broadside) of fish.

Jinshan Xu raised concerns that the sonar location for FORCE's mobile fish surveys may be too close to the ship hull and may have contributed to the entrained air observed on Echograms. Ultimately, the panel felt that this was a fairly standard approach and bubble scattering was due to turbulence from the flow, not from the ship hull. Tom Weber felt that measurements should be made as deep as possible to reduce bubble density. Dan Hasselman noted that the flow can be energetic enough to entrain bubbles all the way through the 20 m water column.

It was suggested that lowering frequency would reduce the scatter from bubbles. John Horne cautioned that going down in frequency could impact marine mammals (MM). After a short discussion, it was concluded that the harbour porpoise is the only MM in the area, and we should first see if we can select a frequency that maximizes the signal-noise ratio (SNR) for this problem and then deal with MM mitigation for the harbour porpoise as required.

Joe Hood and Brendan Harvey contributed substantially to an important discussion on signal processing that was on-going throughout the meeting. Several important points came out of this:

1. Echoview is the standard for fishery acoustics but the video displays substantially compress the dynamic range from as much as 24 bits down to about 8 bits. Doing this throws away a

substantial amount of information. Fortunately, Echoview does enable one to access the raw data. Much of the raw acoustic data collected for the tidal energy project has been stored. FORCE will enquire as to the release conditions on the data. This data should be mined to see if there are better approaches to detection, classification, localization and tracking (DCLT).

2. There may be gains obtained by using more complex time-frequency signals than current systems use. This includes optimizing (or at least improving) the center frequency, the bandwidth, and the pulse type of the transmitted signals.

3. Classification, rather than simple detection, should be investigated. Currently much of the classification is done manually by visually assessing the data. Do fish echoes have features that make it look different than the scatter which would help identify fish? Tracking may also help reduce false alarms. (Note that the small field of view that would be a by-product of the very short range sonar suggested earlier would adversely effect tracking.) John Horne noted that tracking work is being done by tagging fish and sending them through scale models of a tidal device this summer.

4. There was general consensus that we are probably not at the limit of technology but commercially available technology might not be suited for this application. In general, try to avoid using consumer grade (COTS) software. Data is being processed and information might not fully convey the total information that is gathered. Accessing the raw data will enable analysis using scientific algorithms written in high level languages such as IDL or Matlab to see if improvements can be made.

John Horne provided some background on monitoring: Biomass estimates are based on echo integration. Must look at pulse widths and frequencies. Detectability probability of frequent targets. Split beam algorithms for single targets. During tidal cycle you will have echo integration as opposed to echo counting of individual targets. Densities will be species-dependent. Aggregations that you would see through tidal cycle will depend on combination of species and turbulence and tidal state. Colour palette might be biasing interpretation of data. Full digital data is available that can be used for full analytic capability from EK80. To look at detection of fish in turbulent zones he recommended the paper by Fraser et al. (Automatic active acoustic target detection in turbulent aquatic environments, 2017 in Limnology and Oceanography: Methods).

John Horne said that current detection in the fish acoustics field uses Target strength first– amplitude-based to discriminate frequencies; 2nd is multi-frequency differencing – differences in wavelengths and direction of targets. With availability of broadband signals there is renewed interest in full spectrum or partial spectrum comparisons. What's come from that is machine learning and AI for characterization of unique signatures. Constructive and destructive interference on fish bladder from fish body and outside sources. Body plus swim bladder returns from an animal must be considered and swim bladder cannot be the only defining characteristic.

Craig Brown strongly advocated for ground truth validation of any detection and classification estimates.

Sara Stout-Grandy noted that Vemco/Innovasea and Acadia University (Dr. Anna Redden in the Acadia Tidal Energy Institute) are pursuing some funding to use machine learning on active sonar detections to identify fish around turbines. Dr. Redden has already done a lot of work around turbines in the Bay of Fundy with Vemco's fish tracking equipment. (Note: Machine learning for this purpose is also being worked on in Norway by Niels Hendergard at IMR.)

There was some discussion on monitoring animal-device interactions vs. monitoring population effects (domain monitoring) which require different approaches. While monitoring in other jurisdictions (i.e. United Kingdom) suggests that turbine interactions with individual marine animals are relatively rare, the nature of these interactions in the Bay of Fundy has yet to be quantified and needs to be addressed. Domain monitoring—are the devices affecting the long term health of the population—is far more critical. The species of special status are particularly important (salmon and sturgeon in the case of Fundy). Some feel that the inshore fishing community is against anything going in the water and DFO is not taking a constructive role in managing this process.

David Barclay suggested developing a fluid-acoustic coupled model. Could we go from theory to a model without doing any experimental work, and still feel confident in its performance? Alex Hay responded that we have basic information on turbulence models as a function of flow speed using characteristic measures of turbulence. There is enough information to provide input to such a model although some assumptions would still need to be made. You could have a basis for how the fluid would behave statistically in relation to the sonar. The question is, how will the fish behave relative to the turbulence? What scales of turbulence affect the fish? What is the relationship between turbulence and fish detection other than the presence of bubbles? Answers to these questions could be used as a performance prediction tool to determine subsequent monitoring equipment requirements.

Although the SMEs covered much of the primary expertise needed for the discussion, the consensus was that, given that Echoview is the standard for fishery acoustics, it would be helpful to have had a technical expert on Echoview present at the discussion. Sara Stout-Grandy suggested someone from HTI-Vemco in Seattle as a candidate and Dan Hasselman suggested Haley Viehman. Dan Hasselman suggested a fish-behaviour specialist would be helpful to understand their behaviour around bubbles. It was noted that some species refuse to cross bubble curtains and cetaceans will often form a bubble cloud to surround fish schools to trap them. *Could this technique be used to direct fish away from the turbines?*

Meeting Wrap up: To conclude the meeting the Moderator asked each SME to provide closing comments. Many of the comments were echoed around the table, so they are not attributed to a single SME. These comments are summarized below:

1. A coupled fluid-acoustic model with a short range experiment to validate for single device interaction should be developed.

2. Reprocess the existing raw data using non-COTS software to see if improved detection and classification can be achieved. Survey data from the FORCE site using multibeam data could be useful as well.
3. An approach to wide area monitoring (vs. single turbine monitoring) should also be considered as it is an obvious next-step in environment monitoring.
4. Bottom-mounted sonar data should be processed and analyzed and compared with the ship-based transect data. Differences between these data could help with our understanding of the monitoring challenge.
5. Validation of targets (fish) will be challenging, but is nonetheless critical. An optical system will be deployed along with a multibeam system to provide ground-truth data in an upcoming project with OERA. Ocean mapping might provide context for signal processing.
6. Use multi-frequency EK. Crowd-source the data analysis.
7. Experiment with various waveforms, frequencies and bandwidths, to see what kind of information can be extracted. A thorough review the literature should be done to understand what has already been done.
8. Long term monitoring is important to understand how population is affected. Fixed systems are more efficient for long term modelling.
9. Get statistical models of scattering from fish vs bubbles. For single-device monitoring, one can reduce volume scattering by bringing sonar closer to the targets, or reduce the operating frequency. Depends on target area of fish and field of view. Check with manufacturers to see who wants to test their equipment at the site to get access to equipment. (Note, some nearfield device testing work has been done by a group off Oregon Coast for wave energy test centre.)
10. Examine if there is a threshold at which the bubble field entirely obscures the fish signal.

Appendix A: Post-meeting SME submissions

Dr. David Barclay recommended the following paper on scattering from mixed assemblages:

1. Wu-Jung Lee and Timothy K. Stanton, "Statistics of Echoes From Mixed Assemblages of Scatterers with Different Scattering Amplitudes and Numerical Densities," *J. Oceanic Eng*, **39**, no. 4, p. 740, 2014.

Dr. John Horne recommended the following papers for information on domain monitoring:

2. John K. Horne and Dale A. Jacques II, "Determining representative ranges of point sensors in distributed networks," Springer International Publishing AG, part of Springer Nature 2018, p. 347, May 2018.
3. Hannah L. Linder and John K. Horne, "Evaluating statistical models to measure environmental change: A tidal turbine case study," **84** p. 765, Ecological Indicators, 2018.
4. Hannah L. Linder, John K. Horne, and Eric J. Ward, "Modeling baseline conditions of ecological indicators: Marine renewable energy environmental monitoring," **83** p. 178, Ecological Indicators, 2017.
5. Lauren E. Wiesebron, John K. Horne, Beth E. Scott, Benjamin J. Williamson, "Comparing nekton distributions at two tidal energy sites suggests potential for generic environmental monitoring," Intl. J. Marine Energy, **16**, p. 235, 2016.
6. Lauren E. Wiesebron, John K. Horne, and A. Noble Hendrix, "Characterizing biological impacts at marine renewable energy sites," Intl. J. Marine Energy, **14**, p. 27, 2016.

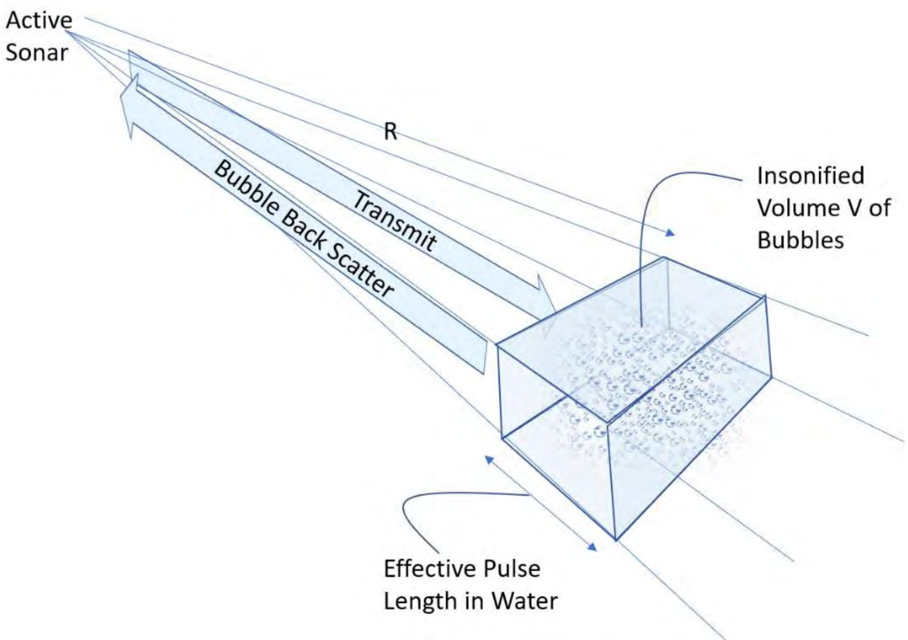
Dr. Sara Stout-Grandy submitted the six seed questions contained in the agenda to her colleagues at HTI-Vemco in Seattle (http://www.htisonar.com/). They have about 30 years of experience using their echosounder around DAMs to monitor/track fish around them. Below are their replies:

a. Q1. Are existing linear acoustic models sufficiently accurate for this environment? (small amplitude, and more importantly, no rotational flow, i.e. Curl= 0). The propagation model (I think) this question is addressing is probably not that important for our work. We would probably locate the transducers so that fish targets were 10s of meters (not hundreds of meters) way from the transducer. Over those distances, arrival times and amplitudes would not be altered that much. Most of the parameters we might consider for species identification would be related to aggregations of returning echoes (tracks), or possibly relative amplitudes of discrete frequencies. What might come into play is Doppler shift of the echoes if the fish targets are moving very fast. Another possibility would be variability in amplitude or variability in pulse length of echoes.
b. Q2. Does entrained air represent a physical limit or can we design systems around it? Yes air is a serious problem– although lower frequencies may allow limited improvement in some cases. Also, forward scattering has been used to retrieve at least some data in very poor acoustic environments, although only presence/absence is likely to be available.
c. Q3. Are active sonars at their functional limits, or are they just poorly matched to work in turbulent flow? There are certainly areas that could be explored, but these are primarily in the data processing end – not so much the physical sound transmission and reception aspect of the signals. Looking at multiple channels and Doppler shifts (as the HR3 tag receiver does) might be one such avenue to go down.

d. Q4. Will we get more traction from increasing Signal, or decreasing Noise? Either way would help! Our challenge has always been that the electronics have very low noise and is insignificant compared to the environmental noise – which we cannot control. I'm not sure about how some sort of active noise-cancelling scheme might work with narrow-band acoustics, but maybe there is something there. We have been successful at increasing signal by using wide-band signals (FM slide) and matched filter processing – perhaps there are more aggressive ways to use these techniques to get better results.
e. Q5. Will we get more traction from improving hardware (sensors) or improving software (DCL?) I think that the software side is where significant advances will come – in terms of capabilities. Sensors are well developed – although the best ones are still expensive. Improvements to hardware will likely be to bring the price down.
f. Q6. What should we be measuring/modelling *right now* to fast track progress in this topic? Water velocities and physical mounting, aiming, and coverage requirements have always been major challenges. Knowledge about species present, behavioral data, and fish sizes is also helpful.

Dr. Ron Kessel of Seamout Analytics (https://seamountanalytics.ca/) submitted the following observations to the panel shortly after the meeting closed.

The troublesome fish-masking phenomenon illustrated at the outset of the workshop, for an echo sounder using the Echoview software, was variously attributed to "bubbles", "turbulence", "noise", "reverberation", and "volume scattering". The worst term is *turbulence*. It is like using the term "wind" for clouds in the sky. Turbulence below super sonic speeds is invisible to sonar except insofar as the turbulence happens to entrain bubbles, sediments, or thermal/salinity/density contrasts. The best terms are *volume reverberation* or *volume scattering,* which expressly feature in the sonar equation (R. Urick, Principles of Underwater Sound, 3rd Ed). Volume scattering strength for wind-wave injected bubbles is included in the sonar equation by Medwin and Clay for instance (Medwin and Clay, Fundamentals of Acoustical Oceanography). When bubbles mask targets as in the echo- sounder data, the sonar is *reverberation limited*.



Signal to Noise Ratio: Assuming spherical beam spreading, the received signal (in dB) from fish decreases by the two-way propagation loss −2 × 10 log10 R2 = −40 log10 R, while the backscatter from a uniform bubble cloud is the combined effect of the two-way propagation loss and the increasing size of the scattering volume −40 log10 R + 10 log10 R3 = −10 log10 R. The signal-to-noise ratio (SNR) for fish in a uniform bubble cloud therefore decreases as −40 log10 R + 10 log10 R = −30 log10 R. SNR for fish in a uniform bubble therefore decreases by 9 dB for every doubling of range. This is a severe range limitation. It applies for conical echo- sounder beams as well.

Bubbles also increase the sonar propagation losses through a bubble cloud. This is bubble extinction (cf. Medwin and Clay, Fundamentals of Acoustical Oceanography or Kessel, “Bubble Extinction Model”, Maritime Way Scientific Technical Note, 16-May-2017). If bubbles are confined to the sea surface, then bubble extinction can decrease the received fish signal owing to higher two-way propagation losses through the bubble cloud. Bubble extinction does not change the conclusions in point 2 above because extinction affects the fish signal and bubble backscatter levels to the same degree in a uniform bubble cloud.

Volume backscatter from bubbles decreases as the:

a. insonified volume V decreases, by:

i. increasing the sonar resolution (narrowing the sonar beam);
ii. decreasing the effective pulse length in the water (increasing the sonar bandwidth);
iii. decreasing the survey range R, by surveying/monitoring a smaller water volume, such as in the immediate vicinity of a turbine for instance.

b. sonar frequency is decreased—whose benefit generally is countered somewhat (perhaps entirely?) by the increasing beam width (insonified volume) that attends lower-frequency sonar when size and cost are constrained.

Monitoring of fish in the immediate vicinity of a turbine, on distances on the order of 20 m to 50 m, using high-resolution multi-beam imaging sonars might be considered (e.g., BlueView P450, RESON Seabat 7128, and possibly the much shorter range and much higher-frequency DIDSON sonar). High resolution imaging sonars:

a. dramatically decrease the volume V for bubble backscatter owing to both the smaller region of interest and the very narrow beam widths of multibeam imaging sonars (on the order of 0.5 to 1.5 degrees). It is expected that bubbles will not be a problem, but this is must be tested in situ.
b. give near visual quality scene rendering with fish evident (presumably restrictions on fish body and schools size apply), with the immediate understanding and impact that visual scenes have for non-experts concerned about impact on fish.
c. should be positioned with the sonar line of sight perpendicular to fish-path into turbine, to maximize the target strength of fish at risk.

Tracking: Imaging sonars are rather like video cameras, with a frame rate equal to the ping-rate of the sonar. Tracking of fish amounts to tracking of high-contrast objects in video imagery. A simple back-of-the-envelope task-based configuration design, coordinating sonar resolution, coverage area, ping rates (frame rate for imaging sonar) could be carried out (Kessel, Pastore, Crawford, and Crowe "Commercial Imaging Sonars for Observing Underwater Intruders", proceedings of the Waterside Security 2008 (WSS2008), Aug 2008).

My experience with the sonar manufacturer's is that they would be happy to provide COVE a loaner sonar for trials.

EchoView: One point to be made about the EchoView viewing of an echosounder echograph is that *any* visual rendering loses echograph information. Why? Because the human eye can discriminate only about 256 monochromatic contrast levels in an image, hence 8 bits of contrast information, in three colours (RGB), which is far below the 24-bit information generally contained in an echograph. High glints in an echograph are usually clipped very severely in visual rendering for instance, losing the information that glints carry. This is not a criticism of EchoView. It is a shortcoming of *any* visual rendering of an echograph by any means. It could be that changing the EchoView rendering parameters far outside their usual regime, or, leaving EchoView aside and applying customized image or signal processing to the echograph, may (emphasize *may*) bring fish out for detection amid bubbles under some conditions.