Addressing Collision Risks in Tidal and River Turbines

COSLA Conference Centre, Edinburgh
February 26, 2019

Ocean Energy orjip™ working to accelerate offshore consenting

OES Ocean Energy Systems ANNEX IV

Today's Workshop

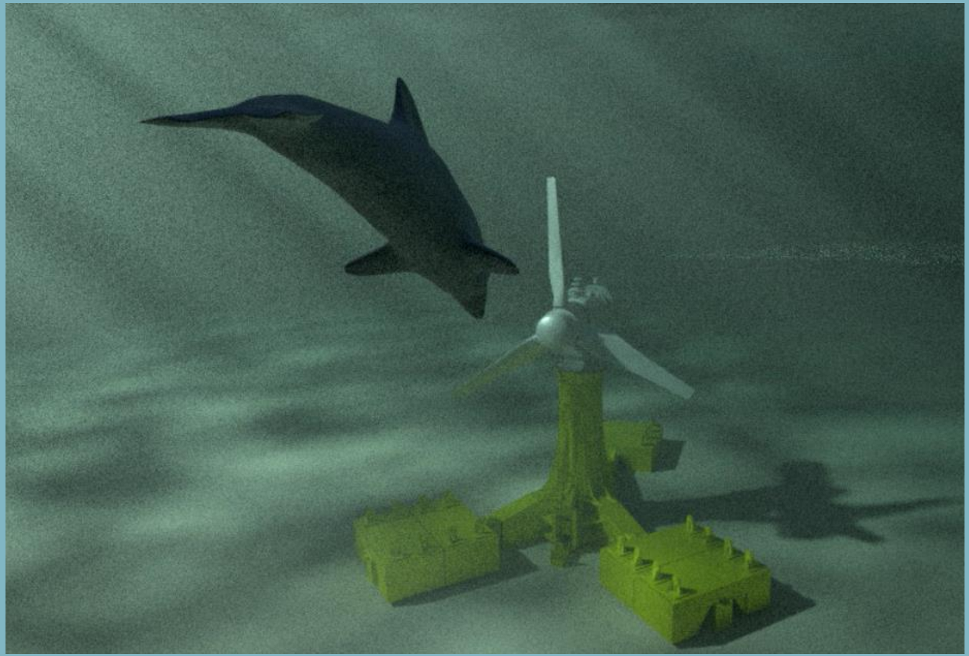
Agenda

1000 – 1015	Introductions and plan for the day (Andrea Copping + Ian Hutchinson)
1015 – 1100	Current state of the science (Carol Sparling + Andy Seitz)
1100 – 1115	Break
1115 – 1155	Development of integrated monitoring platforms • Plug and play platform – Doug Gillespie, St Andrews • AMP – James Joslin, University of Washington, PMEC • FAST – Dan Hasselman, FORCE • FLOWBEC – Benjamin Williamson, University of Aberdeen
1155 – 1230	Realities of environmental monitoring around tidal arrays Discussion session with case study presentations from Daniel Coles, SIMEC Atlantis Energy Kate Smith, Nova Innovation
1230 – 1300	Lunch
1300 – 1500	Break-out sessions: developing strategic research and monitoring projects for priority funding
1500 – 1530	Report out from breakout sessions and group discussion
1530 – 1545	Conclusions and next steps

Collision Risk and Marine Mammals

State of the Science update

Carol Sparling
SMRU Consulting Europe

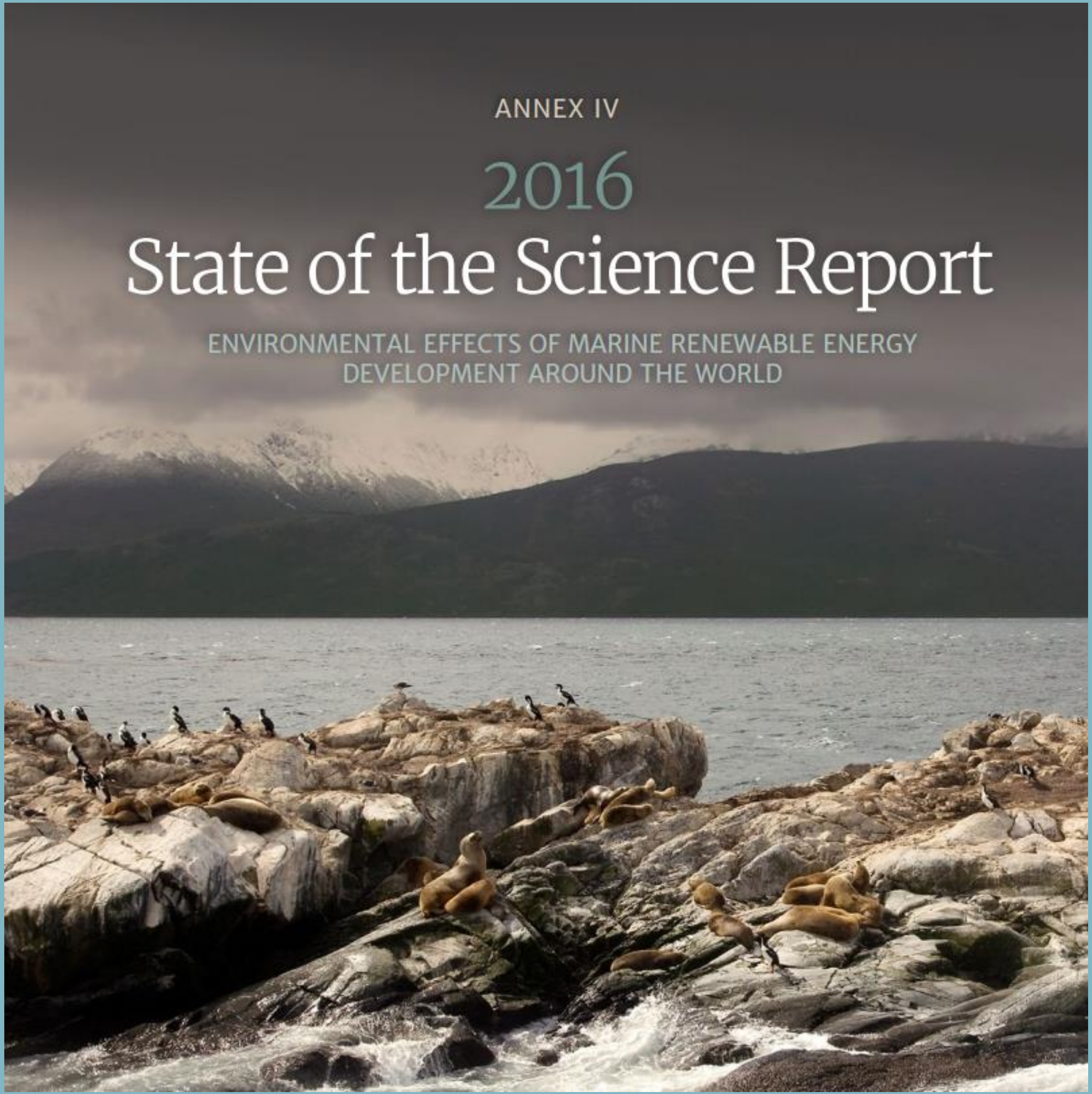


ORJIP Ocean Energy & Annex IV Collision Risk Workshop
26th February 2019

University of St Andrews

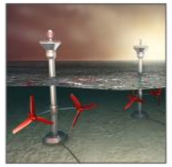
Sea Mammal Research Unit

SMRU Consulting



POTENTIAL FOR ANIMALS TO BE INJURED AROUND TIDAL TURBINES

Collision Risk



POTENTIAL CONCERNS

The presence of marine renewable energy (MRE) devices—particularly the rotating blades of tidal turbines—in the ocean is thought to pose a risk to marine animals and diving birds. Animals might come into close contact with tidal turbine blades in the course of their natural movements; because they are attracted to the device for purposes of feeding, shelter, or out of curiosity; or because they are not strong enough to avoid tidal currents that might sweep them into the blades.

The concern is that collision with a tidal blade (or perhaps the stationary part of a device like the foundation) could cause irrecoverable injury or death. For animal populations that are under stress for other reasons, such as climate change or other human activities, loss of one or a few members due to collision might affect the survivability of the population. The greatest concerns are for marine mammals, especially those in declining populations; commercially and recreationally important fish species; and endangered seabirds.

STATUS OF KNOWLEDGE

No instances of marine mammals, fish, diving seabirds, or other marine animals colliding with an operational tidal turbine have been observed to date. Instrument packages capable of observing animal/turbine collisions are under development, but few have been adequately tested or deployed around an operational MRE device. Laboratory simulations have shown that fish may pass through turbines but very few are likely to be harmed. Modeling studies are being used to estimate the chance of animals encountering an underwater object such as a turbine. Many studies currently focus on understanding movements of marine animals in tidal areas, and tracking their reaction to installed tidal turbines. Most studies in Europe are focused on the interactions of marine mammals, particularly harbor seals, around tidal turbines, while North American studies are examining interactions and possible collisions of fish with tidal turbines. Studies have shown that a marine mammal colliding with a tidal turbine may be injured but not necessarily killed, and that animals are likely to recover from many of those injuries.

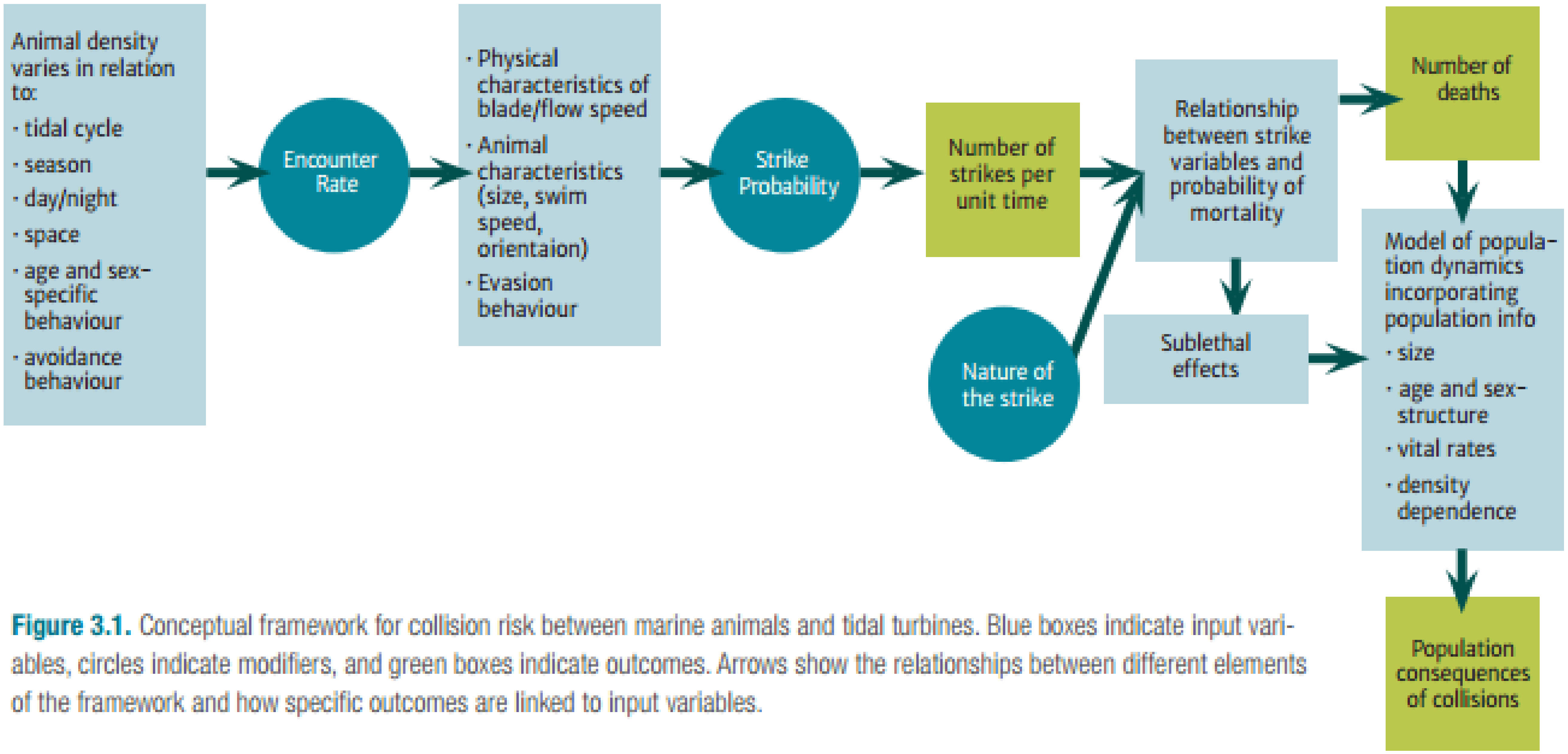


Figure 3.1. Conceptual framework for collision risk between marine animals and tidal turbines. Blue boxes indicate input variables, circles indicate modifiers, and green boxes indicate outcomes. Arrows show the relationships between different elements of the framework and how specific outcomes are linked to input variables.

Progress in a number of areas:

Understanding marine mammal behaviour in tidal environments

Understanding marine mammal behaviour in the presence of devices

Understanding near field encounter rates and behaviour around devices

Understanding the consequences of collisions

Development of techniques, technologies and tools

Lots of lessons learned along the way!

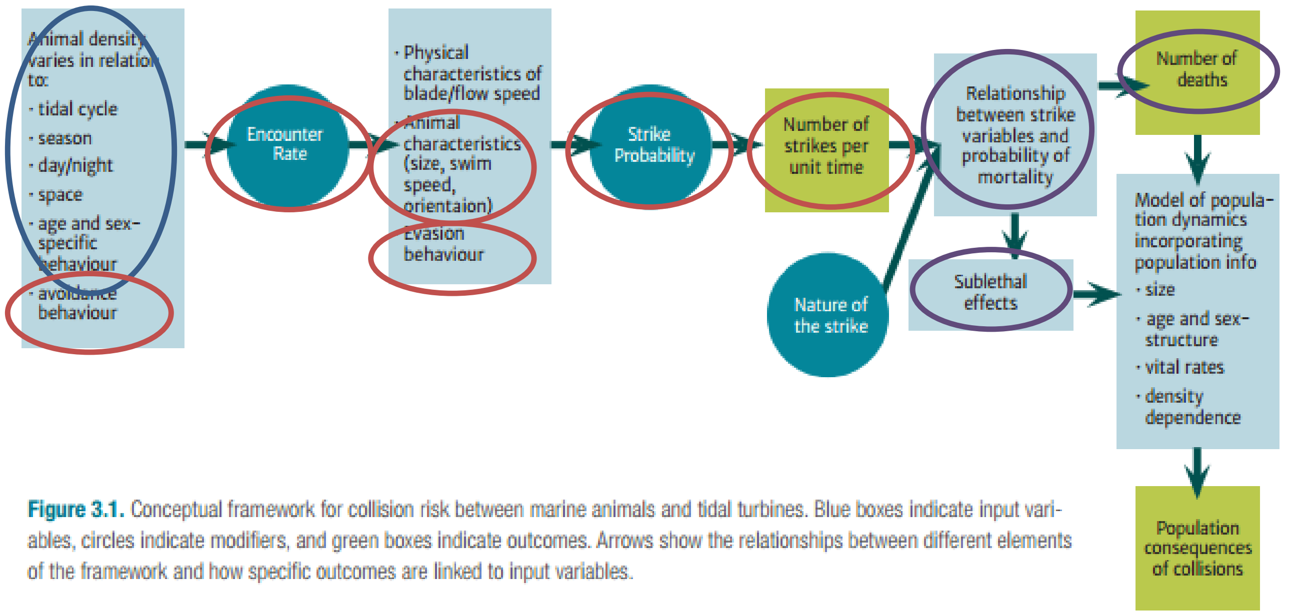
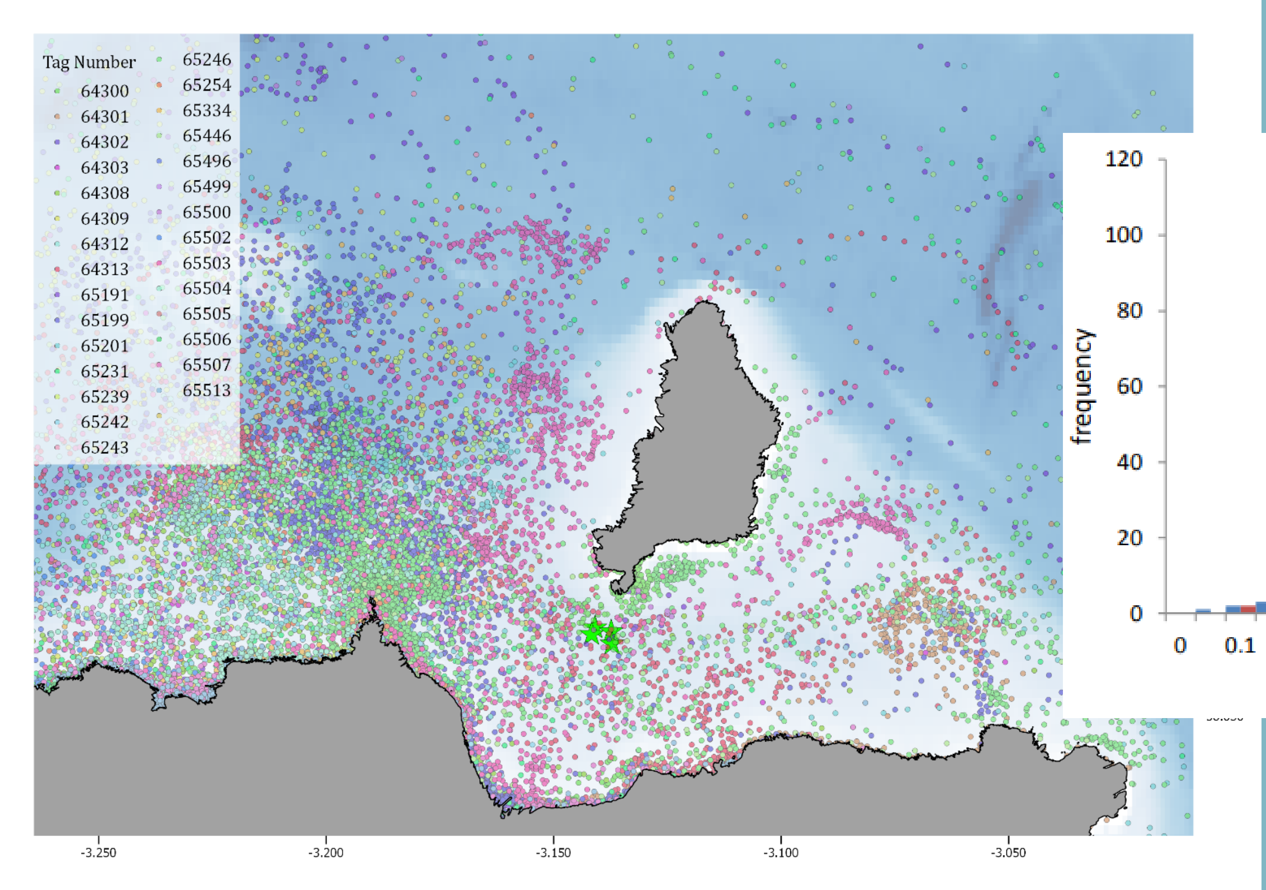


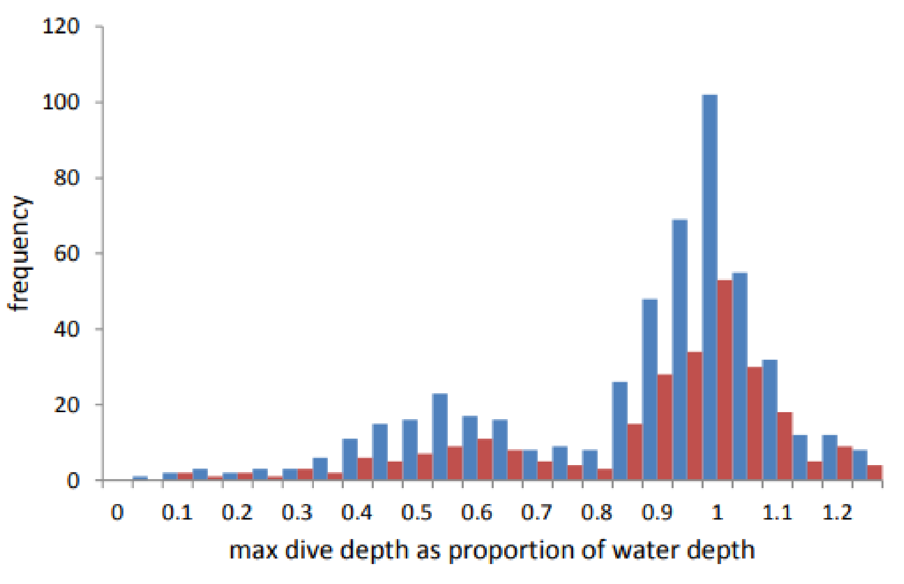
Figure 3.1. Conceptual framework for collision risk between marine animals and tidal turbines. Blue boxes indicate input variables, circles indicate modifiers, and green boxes indicate outcomes. Arrows show the relationships between different elements of the framework and how specific outcomes are linked to input variables.

Understanding marine mammal behaviour in tidal environments

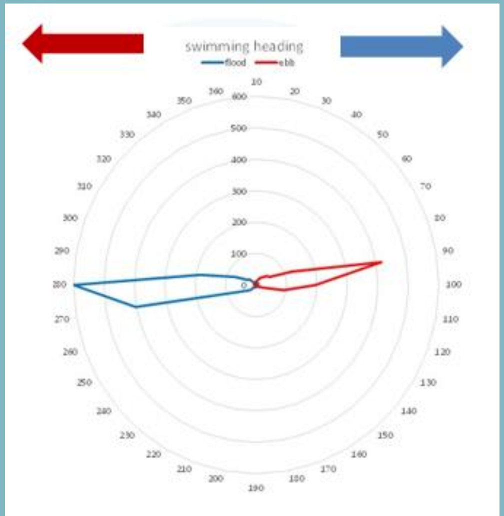
analysis of seal tag data

harbour seals in the Pentland Firth:





Mid-water dives

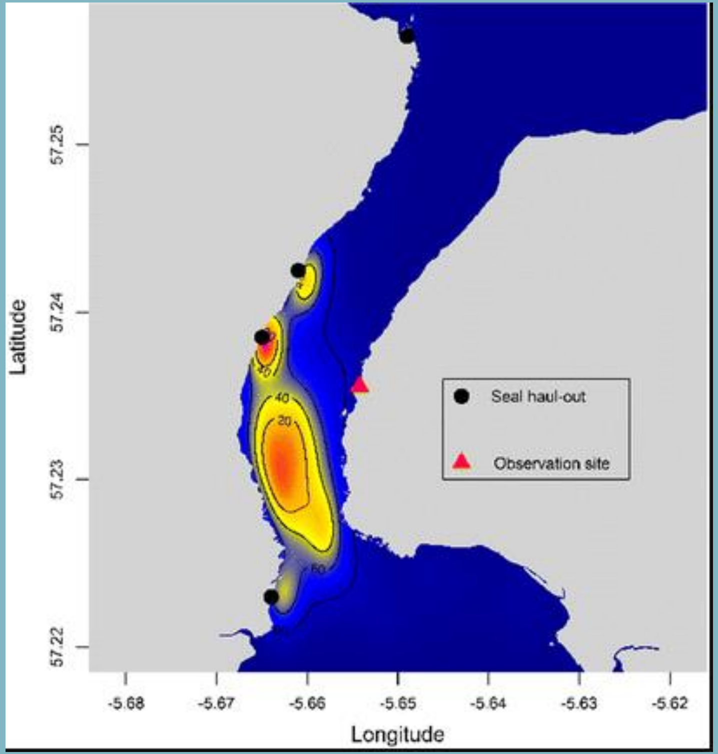


Movement against the current

Joseph Onoufriou's PhD, Sea Mammal Research Unit, early analysis detailed in Band et al., 2016

Understanding marine mammal behaviour in tidal environments

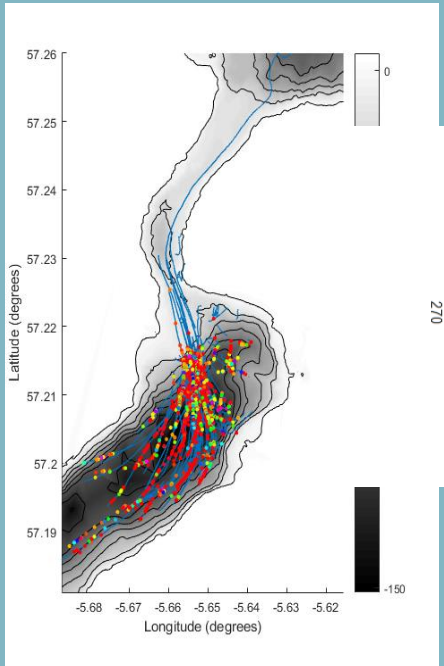
UHF tagged harbour seals in kylerhea

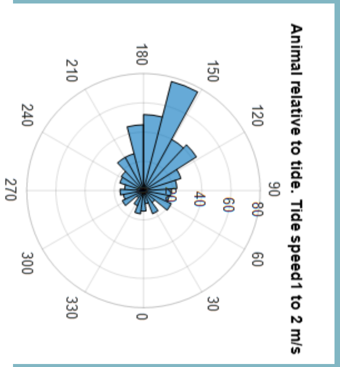


Hastie et al., (2016) Beh Ecol and Soc. 70(12): 2161-2174

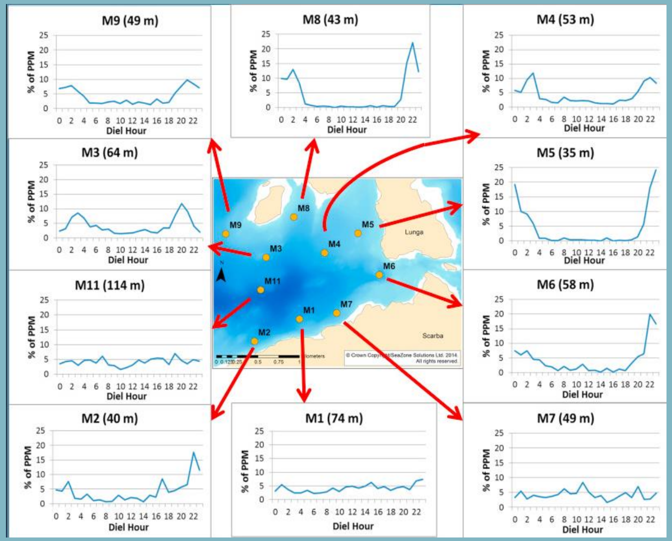
harbour porpoise acoustic monitoring – high spatio-temporal variability, information on depth distributions

Macaulay et al (2017) JASA 141(2):1120-1132

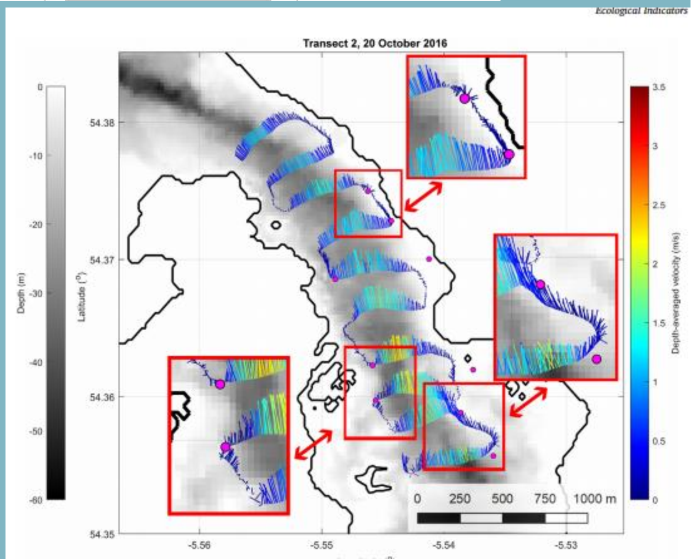




Benjamins et al (2017) DSR II, 141: 191-202



Seal visual observations
Lieber et al (2018) Ecological Indicators 94: 397-408



Monitoring in the presence of devices: SeaGen

Received: 2 November 2016 | Revised: 29 March 2017 | Accepted: 17 April 2017
DOI: 10.1002/aqc.2790

WILEY

RESEARCH ARTICLE

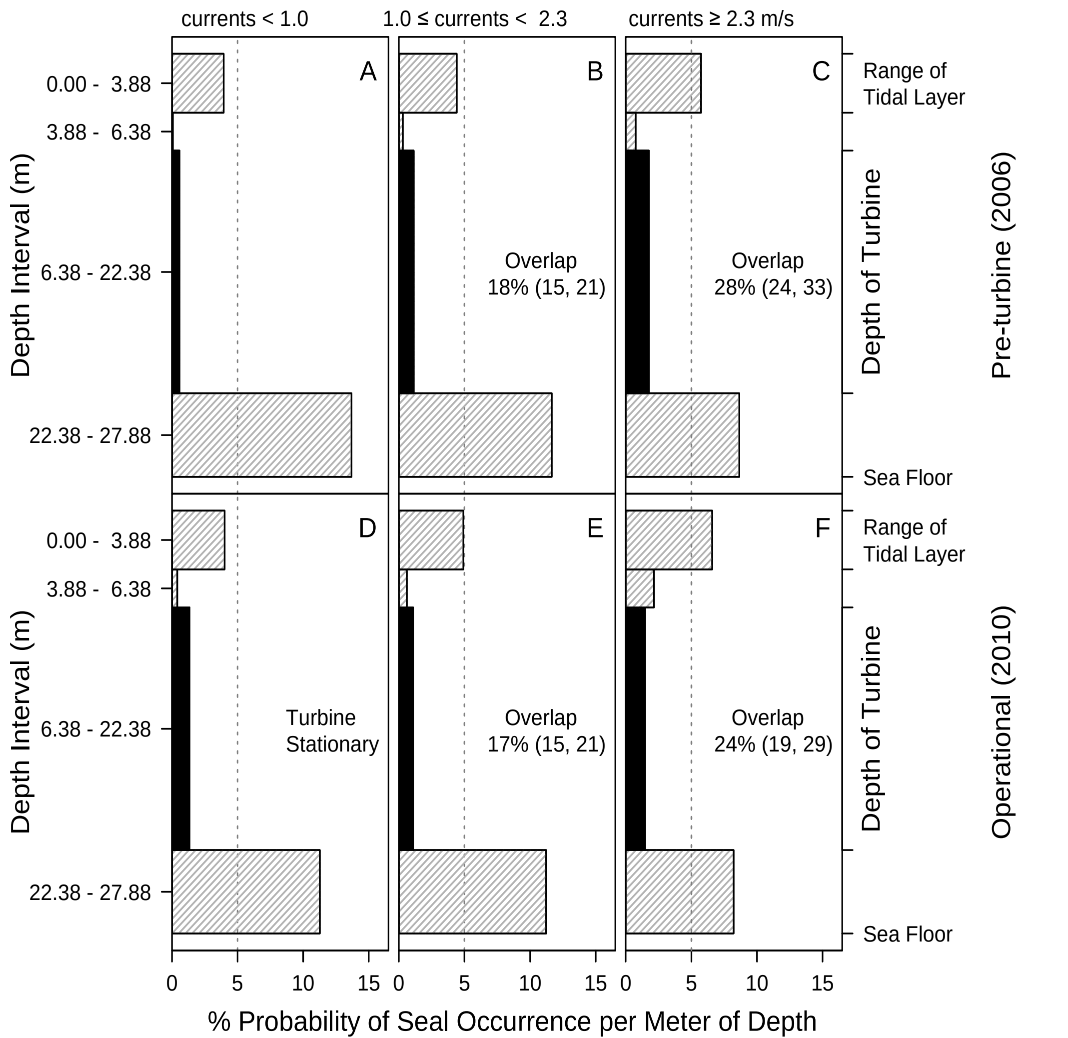
Harbour seals (*Phoca vitulina*) around an operational tidal turbine in Strangford Narrows: No barrier effect but small changes in transit behaviour

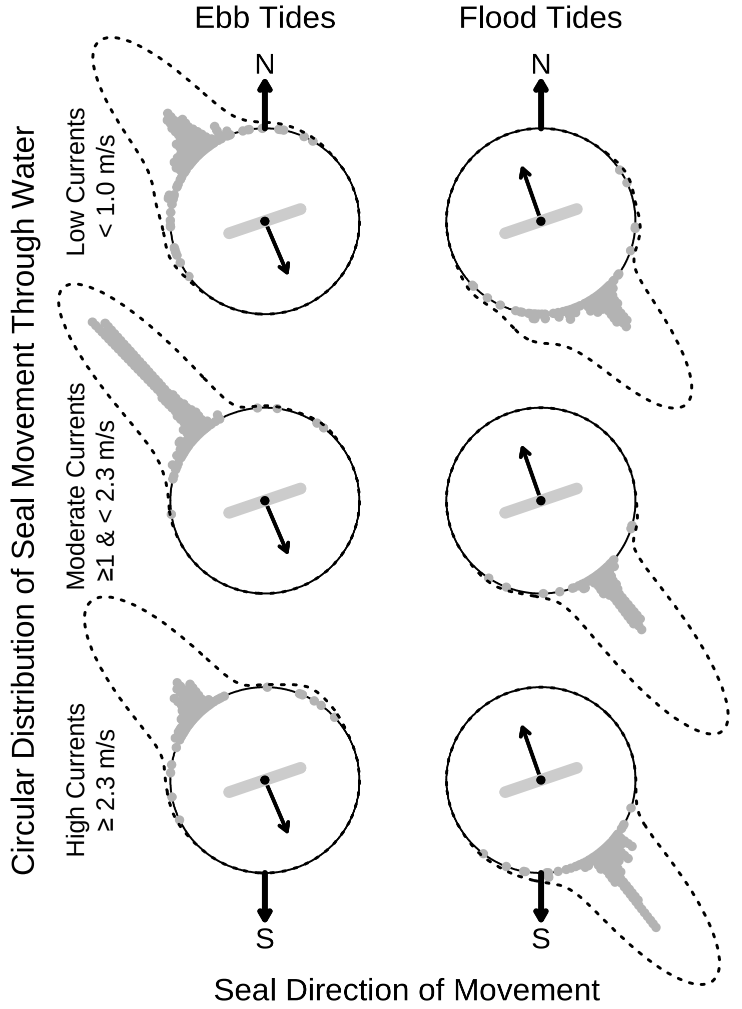
Carol Sparling[3] | Mike Lonergan[1,2] | Bernie McConnell[1]

Marine Pollution Bulletin 136 (2018) 92–106
Contents lists available at ScienceDirect
Marine Pollution Bulletin
journal homepage: www.elsevier.com/locate/marpolbul

Empirical measures of harbor seal behavior and avoidance of an operational tidal turbine

Ruth Joy[a,b,*], Jason D. Wood[c], Carol E. Sparling[d], Dom J. Tollit[a], Andrea E. Copping[e], Bernie J. McConnell[f]





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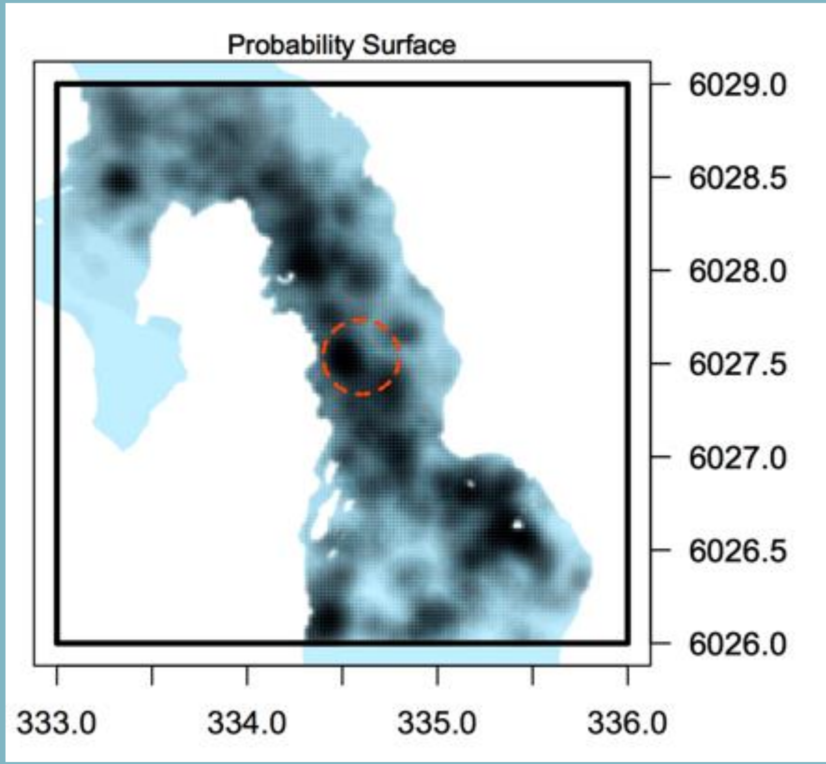
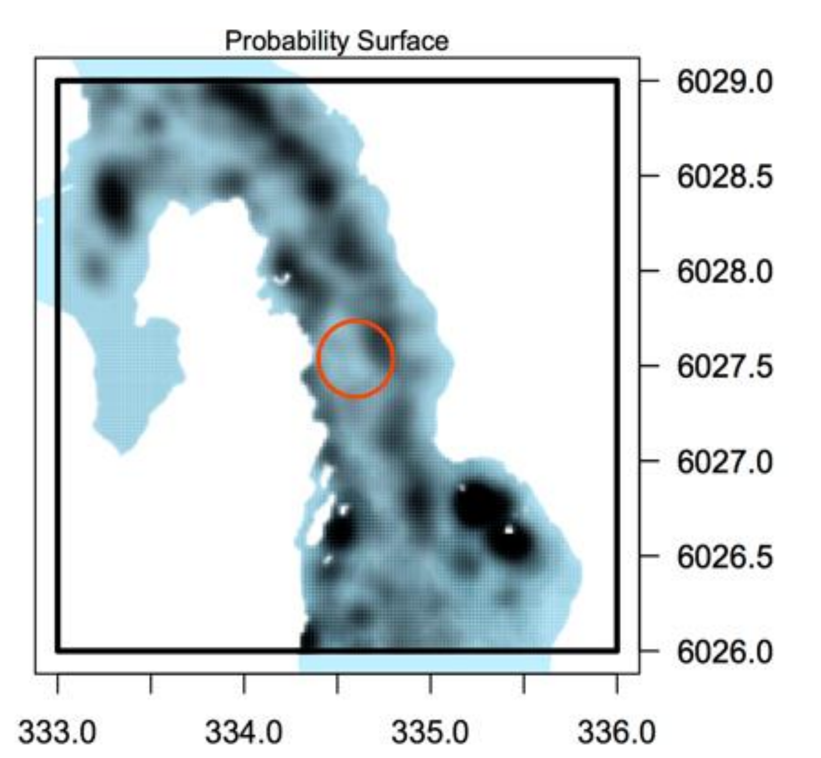




Monitoring in the presence of devices

FORCE, Canada

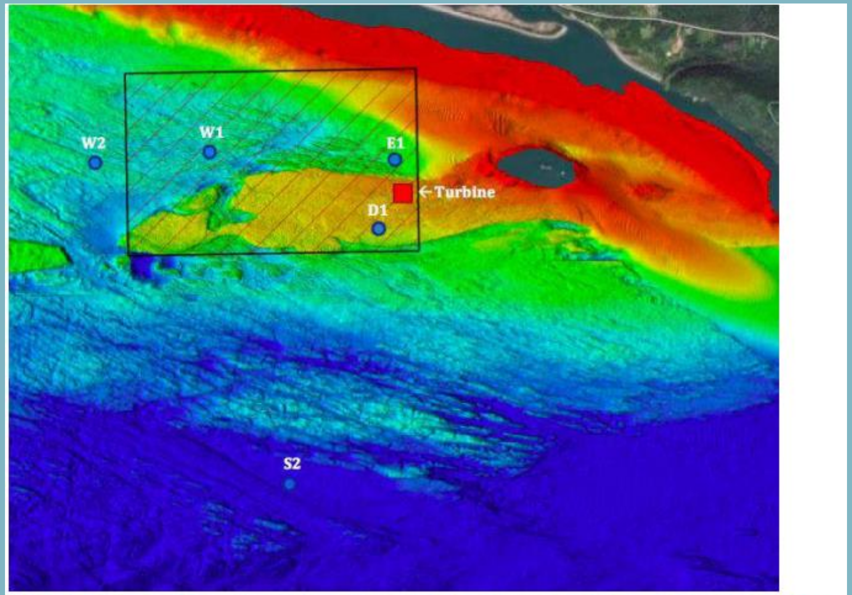
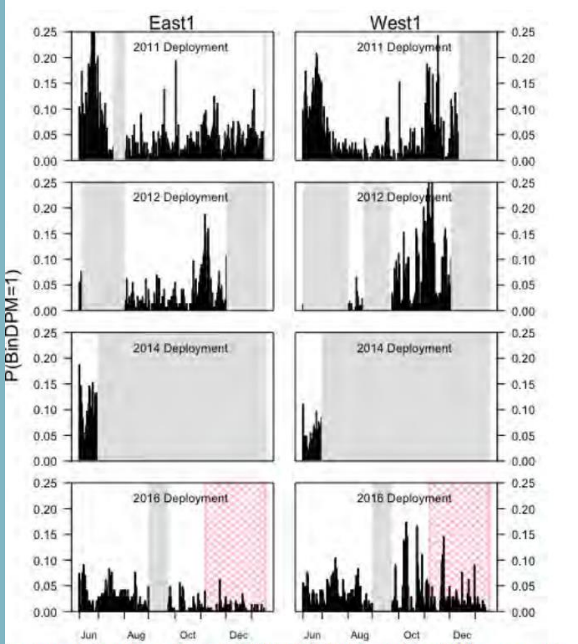


Figure 6. Locations of five monitoring C-PODs and CSTV turbine installed at Berth D. The hatched box denotes the FORCE demonstration area. Shallow water is depicted by warmer colours.



igure 9. Comparing daily porpoise detections (P(BinDPM=1)) between 8 June and 18 January across 4 ears of deployment. Grey periods denote when the hydrophones were not operational. The pink atching on the bottom 2 panels denote the period when the turbine was installed.

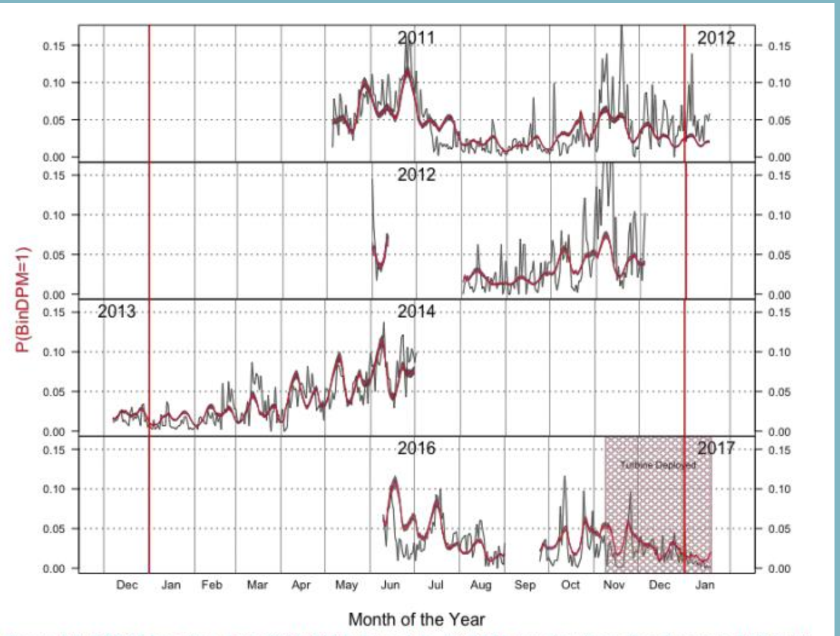


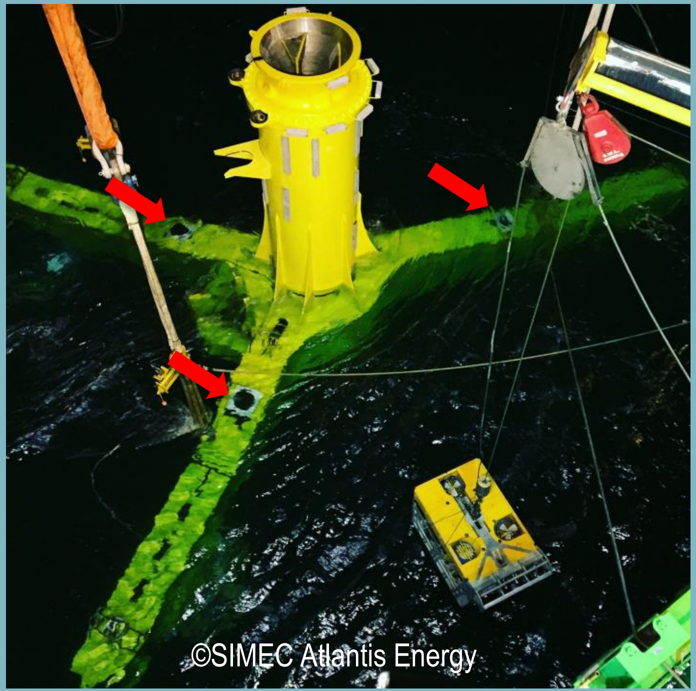
Figure 10. FORCE baseline data 2011-2017. Raw data BinDPM per day (grey lines) versus GEE-GLM model predictions of the overall mean probability of porpoise detection per time bin (PBinDPM) over time (red line).

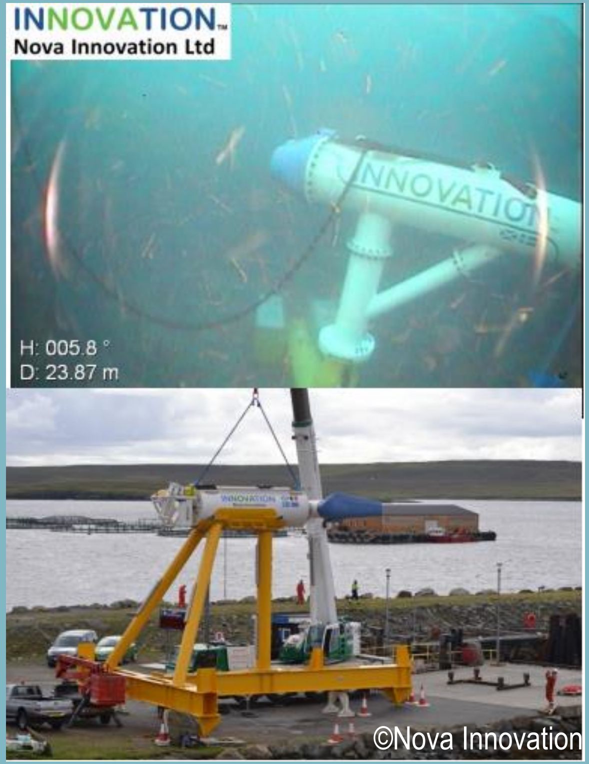
Acoustic monitoring of porpoise activity at FORCE – high variability in detections but significant reduction during installation and operation of the Cape Sharp tidal turbine but no mid-range exclusion (200-1710m)

Joy et al (2017) 1st year monitoring report FORCE EEMP
http://fundyforce.ca/wp-content/uploads/2012/05/Q4-2017-FORCE-EEMP.pdf

Monitoring the near field encounter rate and near field behaviour around devices

Data from a growing number of studies using various technologies to monitor around devices……

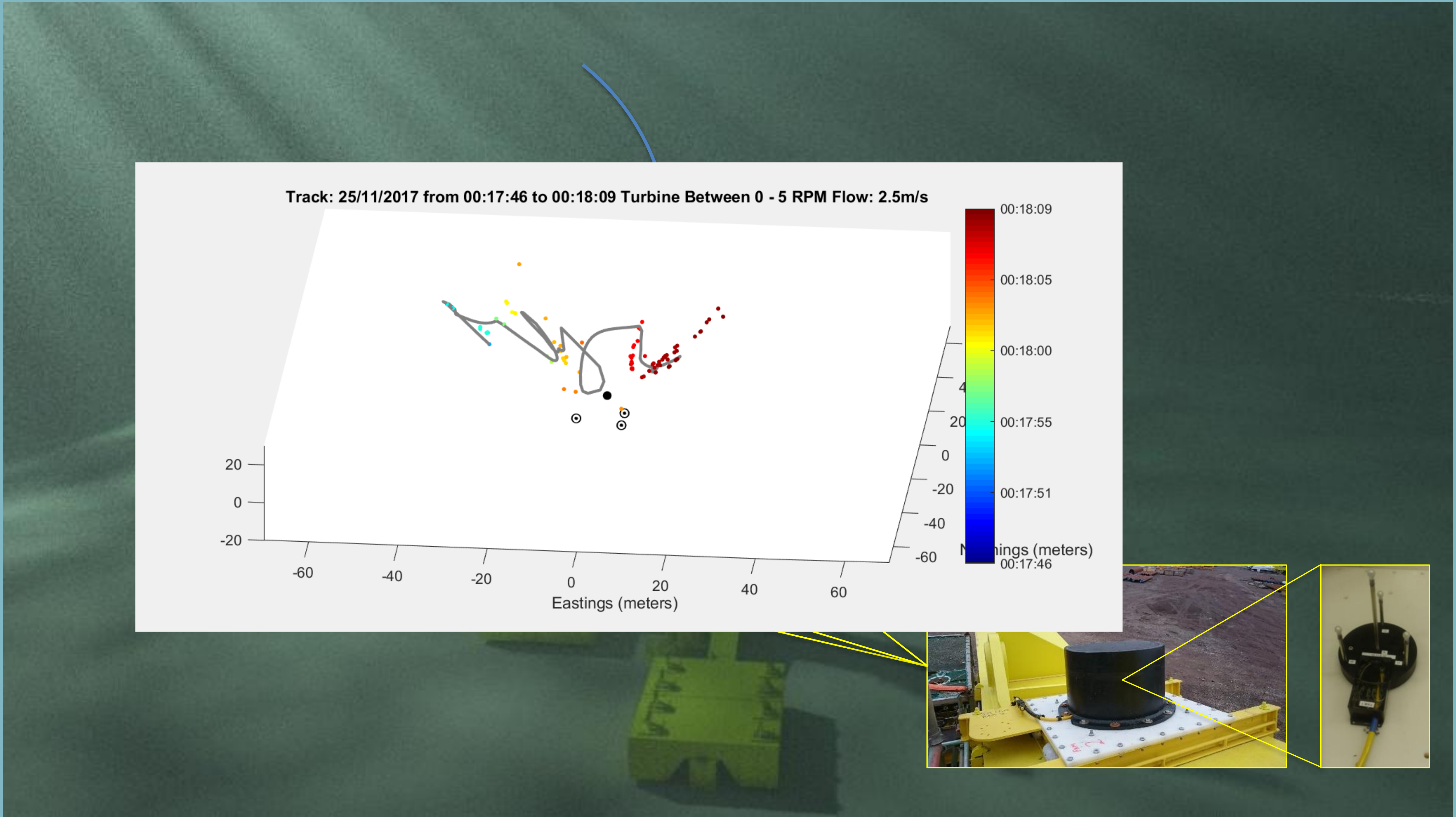




Malinka et al. (2018) MEPS 590:247-266

And others…………..

Monitoring the near field encounter rate and near field behaviour around devices – MeyGen PAM array



Understanding marine mammal prey behaviour in tidal environments and around devices....

ELSEVIER
Energy Reports
Volume 4, November 2018, Pages 65-69
open access

Research paper

Fish distributions in a tidal channel indicate the behavioural impact of a marine renewable energy installation

Shaun Fraser [a] [1], Benjamin J. Williamson [b, 2], Vladimir Nikora [a], Beth E. Scott [b]
Show more

https://doi.org/10.1016/j.egyr.2018.01.008
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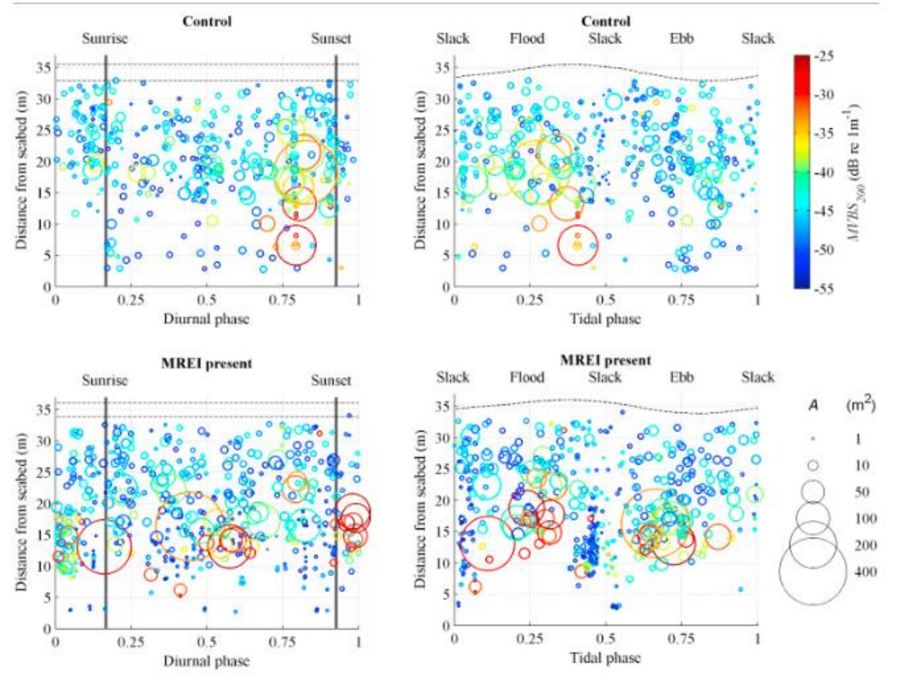


PLOS ONE

RESEARCH ARTICLE

Multi-scale temporal patterns in fish presence in a high-velocity tidal channel

Haley A. Viehman, Gayle Barbin Zydlewski*
School of Marine Sciences, University of Maine, Orono, Maine, United States of America
* gayle.zydlewski@maine.edu

Check for updates

Abstract

The natural variation of fish presence in high-velocity tidal channels is not well understood. A better understanding of fish use of these areas would aid in predicting fish interactions with marine hydrokinetic (MHK) devices, the effects of which are uncertain but of high concern. To characterize the patterns in fish presence at a tidal energy site in Cobscook Bay, Maine, we examined two years of hydroacoustic data continuously collected at the proposed depth of an MHK turbine with a bottom-mounted, side-looking echosounder. The maximum number of fish counted per hour ranged from hundreds in the early spring to over 1,000 in the fall. Counts varied greatly with tidal and diel cycles in a seasonally changing relationship, likely linked to the
winter and spring, higher hourly c
tides near sunrise and sunset. In s
shifted to night and occurred durin
linked to current speed, and did n
observations at other tidal power s
rate of fish with an MHK turbine at
risk to fish is similarly variable. Th
at this site will likely be present at
ing these observations useful in p
worldwide.

OPEN ACCESS

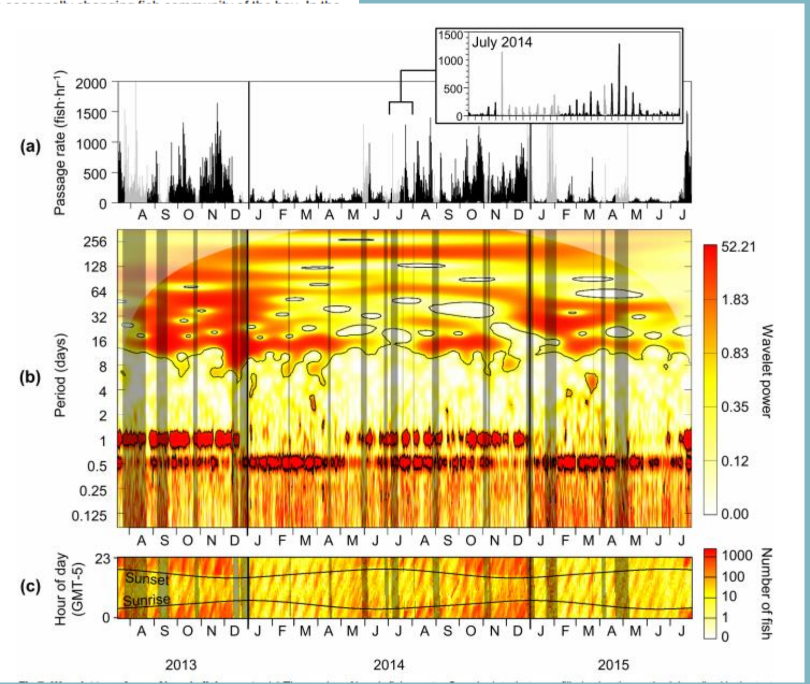
Citation: Viehman HA, Zydlewski GB (2017) Multi-scale temporal patterns in fish presence in a high-velocity tidal channel. PLoS ONE 12(5): e0176405. https://doi.org/10.1371/journal.pone.0176405

Editor: Judi Hewitt, University of Waikato, NEW ZEALAND

Received: October 12, 2016

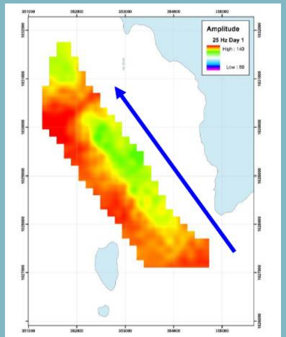
Accepted: April 9, 2017

Published: May 11, 2017

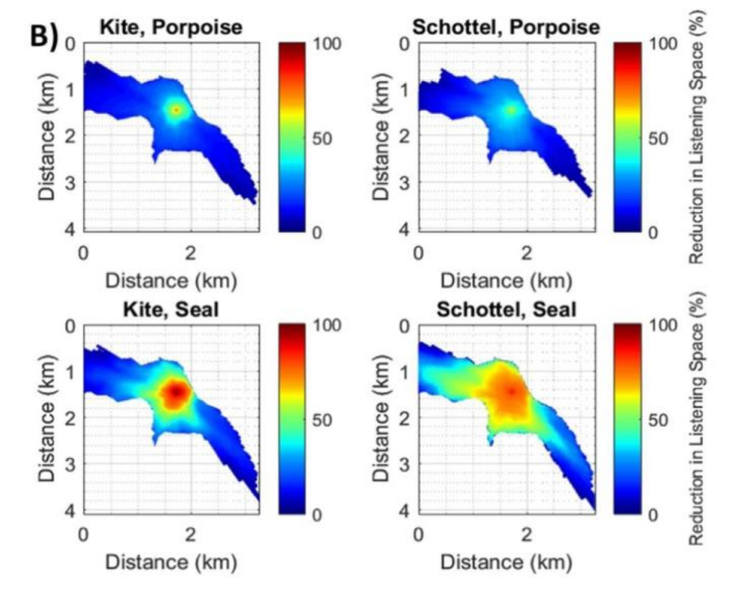


Understanding the acoustic outputs and associated effects of tidal turbines:

Drifting hydrophone studies – SAMS @MeyGen @EMEC

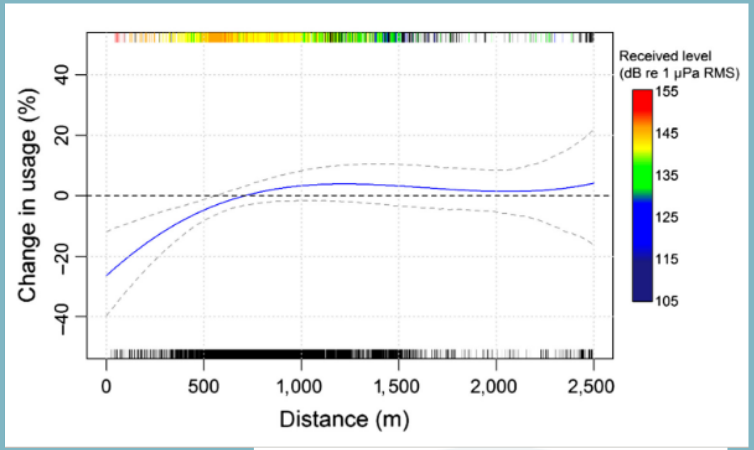


Reductions in effective 'listening space' around turbines
Pine et al., (2019) Renewable and Sustainable Energy Reviews 103:49-57

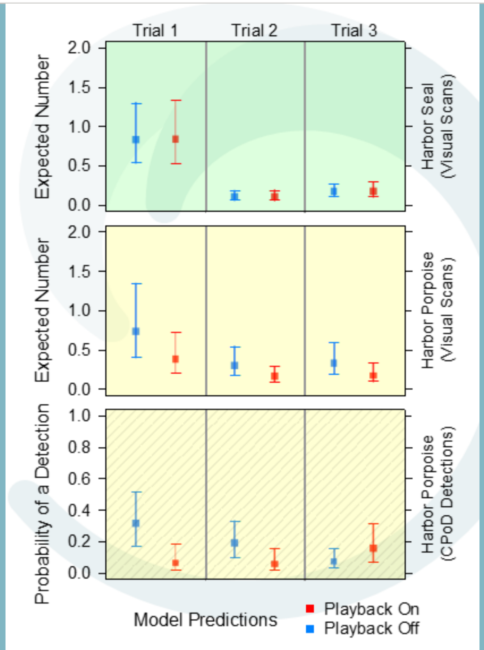


Play back studies:

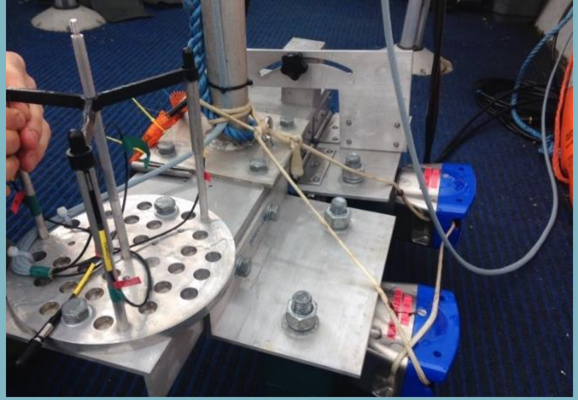
Harbour seals in W Scotland: Hastie et al. (2017) J. Appl. Ecol, 55: 684-693



Harbour seals and harbour porpoises in Admiralty Inlet, WA USA
Robertson et al. (2018) DoE Final technical report for DE-EE0006385



Development of technology and tools:

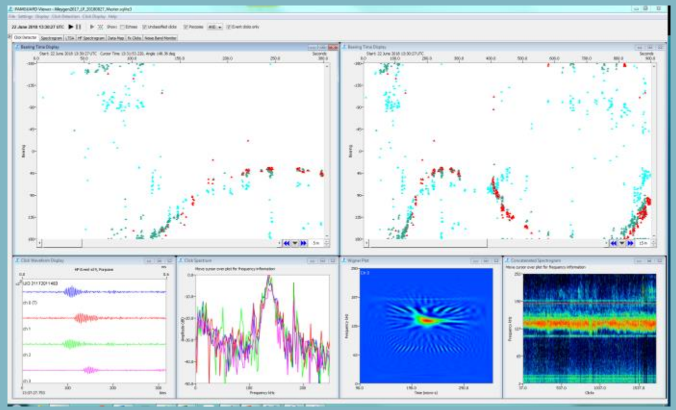


Monitoring tools:

development of 3D AAM tracking, PAM arrays
integrated platforms – FLOWBEC, AMP, FAST, HiCUP (more on these later)
lessons learned from real world deployments (more on this later)

Data management and processing:

DOEIMS study
PAMGuard modules, R packages
detection and classification algorithms for multibeam sonar



Understanding the consequences of collision.. ..

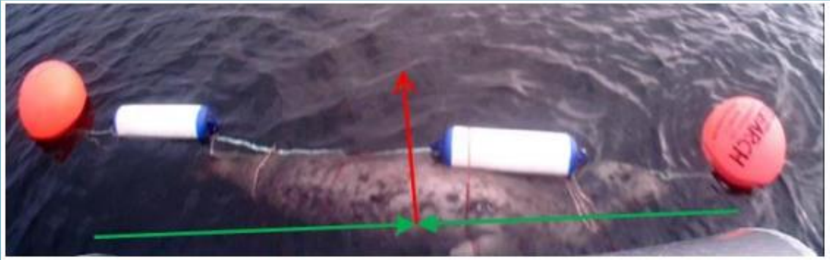
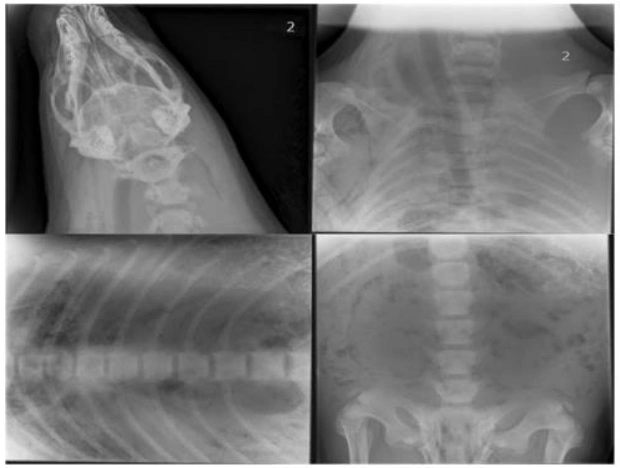
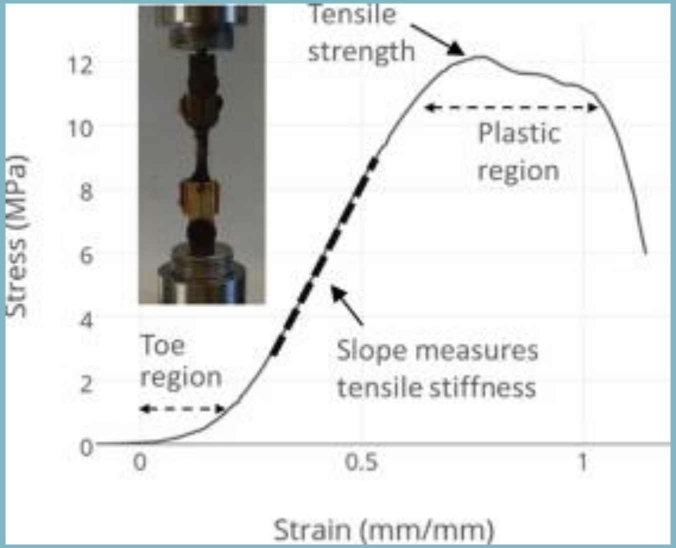


Figure 5. View from bow mounted camera indicating direction of movement and line of impact during an abdomen impact trial. The green arrows indicate the centre point of the boat given the position of the nose piece and the red arrow indicates direction of movement. The point at which the green arrows converge indicates the point of impact on the animal.



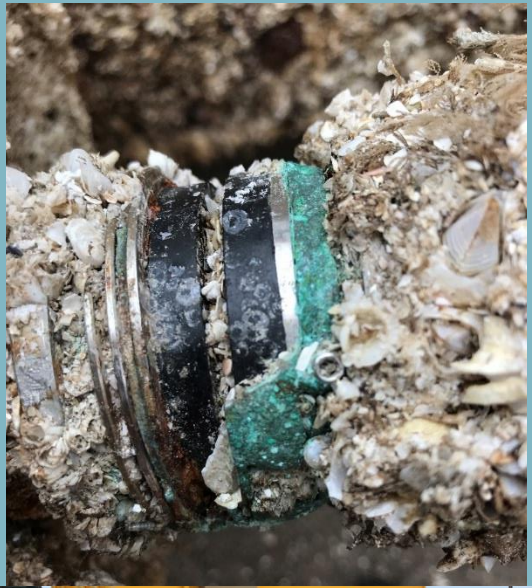
Carcass collision trials:
Onoufriou et al. (In press) J. Appl Ecology

Comparison of Collision Risk with Mortality Risk					
Rotation Speed		12 rpm		6 rpm	
Direction		Upstream	Downstream	Upstream	Downstream
Collision integral	Total	0.283	0.239	0.169	0.143
Mortality integral	Total	0.220	0.192	0.042	0.040
Mortality as a proportion of collisions		77.7%	80.3%	24.9%	28.0%



Models and studies of tissue properties: can be used to help predict response to injury from blunt force trauma
Grear et al. (2017) Zoology 126:137-144

Lessons learned.......



Corrosion…

Connectors….

Interference….

Biofouling….

Sensor placement and orientation….

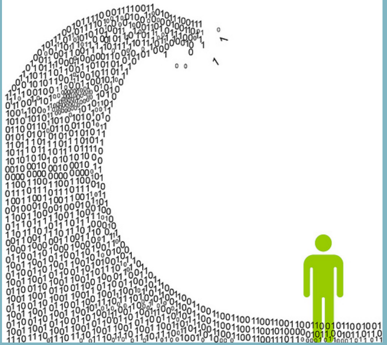
Data Management….

Commercial/academic collaborations….

Conclusions

Lots of progress in key areas…

But… **IMPORTANT TO PUBLISH**



Data management/analysis tools v. important – making sense of imperfect information

Issues of statistical power (monitoring rare events) and our ability to detect collisions still a key gap – will we ever be in a position to categorically detect/rule out collision?

Scaling up to arrays, monitoring design for different turbine types…..?

Thank you

Also to

Gordon Hastie, Doug Gillespie, Laura Palmer, Jamie Macaulay, Joe Onoufriou, Chloe Malinka, Dave Thompson, Bill Band, Ruth Joy, Jason Wood, Dom Tollit, Cara Donovan, Fraser Johnson, MeyGen, TEL, Elaine Tait

Carol Sparling

ces@smruconsulting.com

www.smruconsulting.com

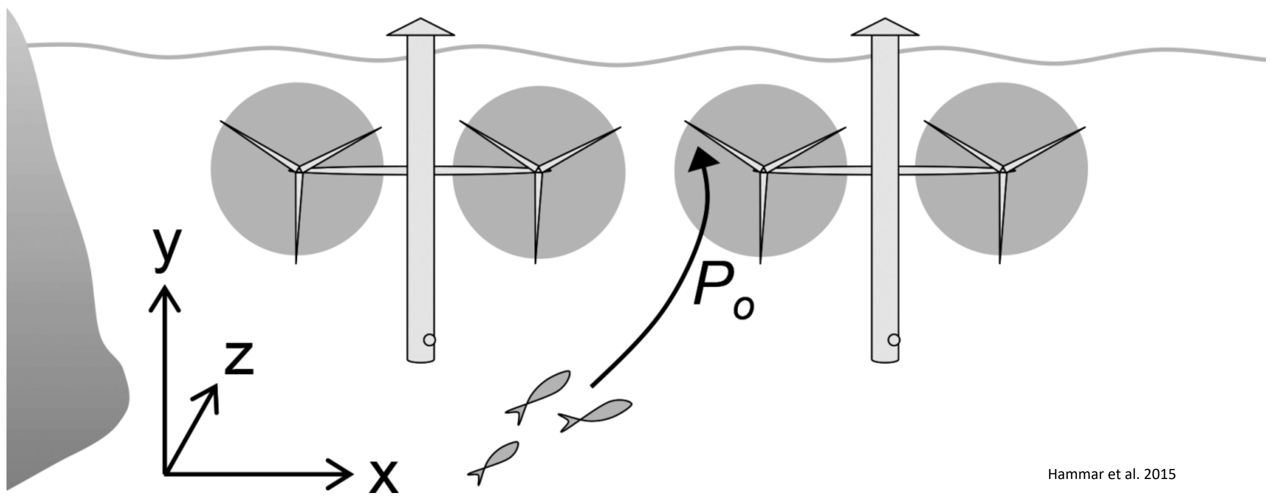
@SMRU_Consulting

Sea Mammal Research Unit

SMRU Consulting

State of the science:

Understanding impacts of tidal and river turbines on fishes



Andy Seitz* and Michael Courtney

University of Alaska Fairbanks

*acseitz@alaska.edu

Overview

- 19 relevant papers (peer-reviewed + gray literature)
  - 10 field study papers
    - 6 tidal study papers
      - 3 fish distribution
      - 3 fish interactions and behavior
    - 4 river study papers
      - 1 fish distribution
      - 3 fish interactions and behavior
  - 6 flume study papers
  - 3 simulation modeling papers

Study species

- In situ studies:
  - In many cases, unknown
  - Atlantic herring (*Clupea harengus*)
  - Atlantic mackerel (*Scomber scombrus*)
  - alewife (*Alosa pseudoharengus*)
  - threespine stickleback (*Gasterosteus aculeatus*)
  - Pollack (*Pollachius pollachius*)
  - saithe (*Pollachius virens*)
  - sprat (*Sprattus sprattus*)
  - sandeels (*Ammodytes spp.*)
  - Pacific salmon (*Oncorhynchus spp.)*

Table 2. Detailed results showing effects on gap passages for fish genera contributing to most of the dissimilarity between control and impact treatment.

Genus	Feeding guild	Body shape	Swimming style	*D* (%)	∑ control (A)	∑ impact (A)	P (A)	∑ control (B)	∑ impact (B)	P (B)
Acanthurus	Browsers	Compressiform	Carangiform	14	190	68	**0.000**	91	5	**0.000**
Chaetodon	Browsers	Compressiform	Carangiform	12	142	50	**0.005**	79	12	**0.011**
Rhabdosargus	Inv. feeders	Fusiform	Carangiform	10	125	71	0.989	101	57	0.912
Ctenochaetus	Browsers	Compressiform	Carangiform	9	131	43	**0.006**	70	18	0.052
Siganus	Browsers	Compressiform	Carangiform	8	95	6	**0.000**	57	0	**0.000**
Thalassoma	Inv. feeders	Fusiform	Labriform	8	113	78	0.478	85	31	**0.019**
Scarus	Browsers	Fusiform	Subcarangiform	7	93	17	**0.000**	53	6	**0.015**
Sufflamen	Inv. feeders	Compressiform	Balistiform	3	17	25	0.191	14	11	0.853
Centropyge	Browsers	Compressiform	Carangiform	3	32	3	0.277	1	0	0.739
Kyphosus	Browsers	Fusiform	Subcarangiform	3	31	1	0.265	0	0	-
Plectorhinchus	Inv./fish feeders	Fusiform	Subcarangiform	3	25	11	0.341	18	7	0.353
Lethrinus	Inv./fish feeders	Fusiform	Carangiform	2	24	19	0.620	11	10	0.739
Pomacanthus	Browsers	Compressiform	Carangiform	2	18	7	0.192	4	0	0.739
Lutjanus	Inv./fish feeders	Fusiform	Carangiform	2	16	1	0.174	8	1	0.247
Parupeneus	Inv. feeders	Fusiform	Subcarangiform	2	13	3	0.072	7	0	**0.007**
Bodianus	Inv. feeders	Fusiform	Labriform	1	14	8	0.512	11	6	0.529
Scolopsis	Inv. feeders	Fusiform	Carangiform	1	6	11	0.738	2	1	0.739

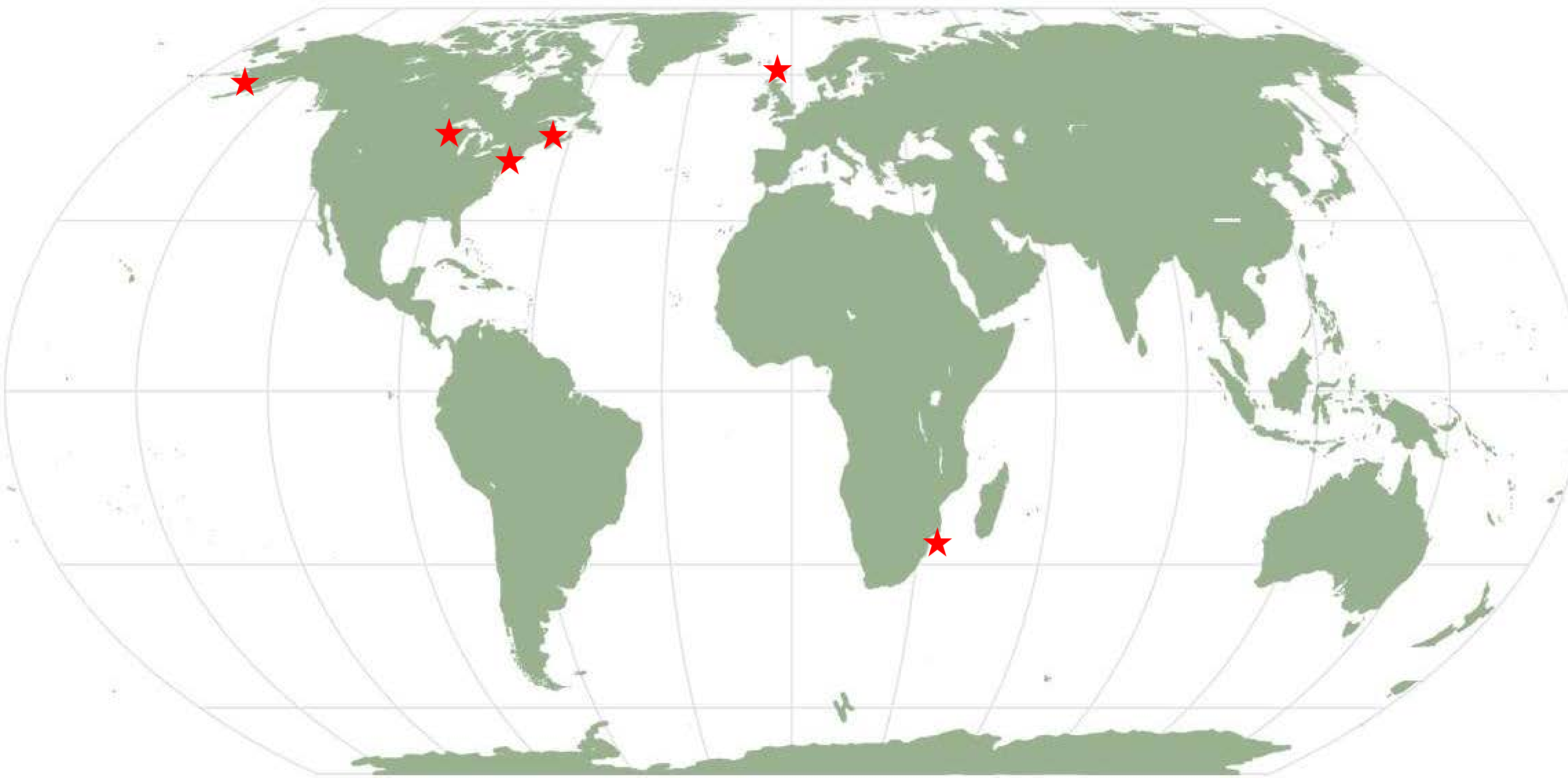
The first columns indicate the taxonomic identity and categories of fish. The genera-specific contribution to the assemblage dissimilarity between fish passing through the gap during control (no rotor) and impact (rotor) is indicated by *D*. Total numbers of gap passages and significance values (*P*) for effects of the rotor (Mann–Whitney *U* tests, using 2×1-sided exact *P*) are presented separately for (A) all samples (n=20) and for (B) samples in current speeds above 0.6 ms^{-1} (n=10). Significant effects are indicated in bold. All non-significant results were associated with low power (<0.8). Only fish genera cumulatively contributing to 90% of the assemblage difference are shown in the table.

doi: 10.1371/journal.pone.0084141.t002

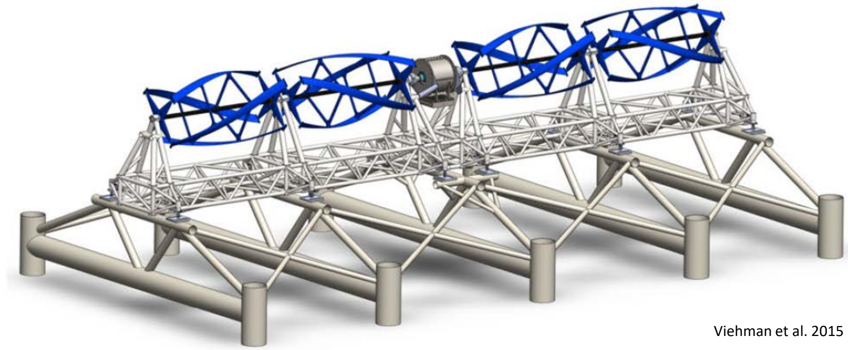
Hammar et al. 2013

- Flume studies
  - Rainbow trout (*Oncorhynchus mykiss*)
  - striped bass (*Morone saxatalis*)
  - hybrid striped bass (*Morone saxatalis x chrysops*)
  - white sturgeon (*Acipenser transmontanus*)
  - Japanese rice fish (*Oryzias latipes*)
  - walleye/sauger (*Stizostedion* spp.)
  - crappie hybrid (*Pomoxis* spp.)
  - fathead minnows (*Pimephales promelas*)
  - yellow perch (*Perca flavescens*)
  - channel catfish (*Ictalurus punctatus*)
  - bluegill sunfish (*Lepomis macrochirus*)
  - Buffalo (Ictiobus spp.)

Study locations

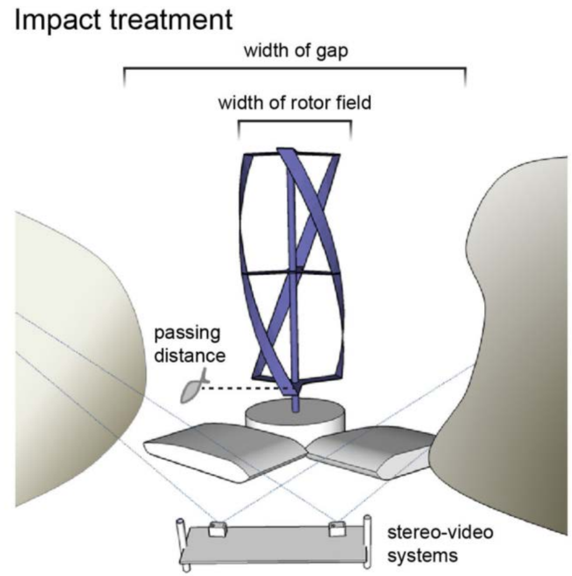


Turbines

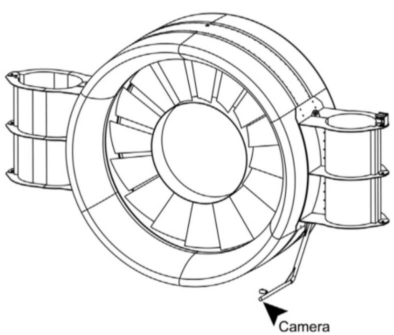


Viehman et al. 2015

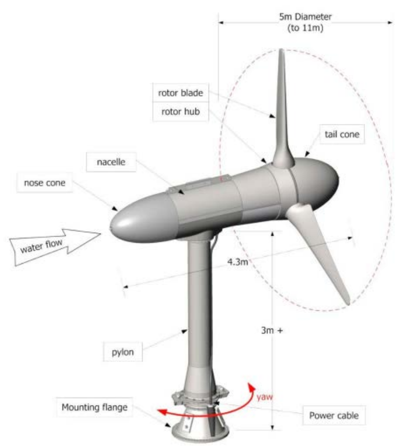
Fig. 1 Ocean Renewable Power Company's TidGen® device (drawing courtesy of ORPC), installed in outer Cobscook Bay in August 2012



Hammar et al. 2013



Broadhurst et al. 2014



Verdant Power Gen 5 KHPS Turbine

Dean Corren 2014

Photo 2. BRI device before deployment, showing mount locations of underwater cameras and light used during deployment in 2014. Water would flow from left to right.

Nemeth et al. 2014

Monitoring approaches

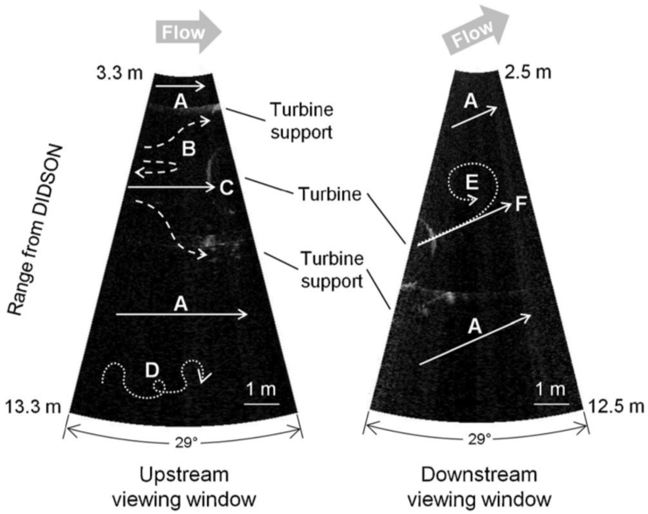


Fig. 3 Sample frames from upstream (*left*) and downstream (*right*) DIDSON units, showing cross-section of the test turbine and its support frame. Fish behaviors illustrated are **a** passing, **b** avoiding, **c** entering, **d** milling, **e** exiting and remaining in wake, and **f** exiting and moving through the wake. Water flow in the downstream view is angled upward due to the angle of the DIDSON   Viehman, H.A., and Zydlewski, G.B. 2015

Figure 4. Example of *Rhabdosargus sarba* (F.) evasion manoeuvre. Goldline stumpnose *R. sarba* carrying out a typical evasion manoeuvre as the specimen passes through the gap against a 0.7 ms^{-1} current speed. The fish changed its trajectory 45° with a quick burst as it was startled by the approaching rotor blade at 22 cm distance. The image was extracted from the analysed video material (right camera).

doi: 10.1371/journal.pone.0084141.g004   Hammar et al. 2013

H. Shen et al. / Renewable Energy 97 (2016) 746–756   749

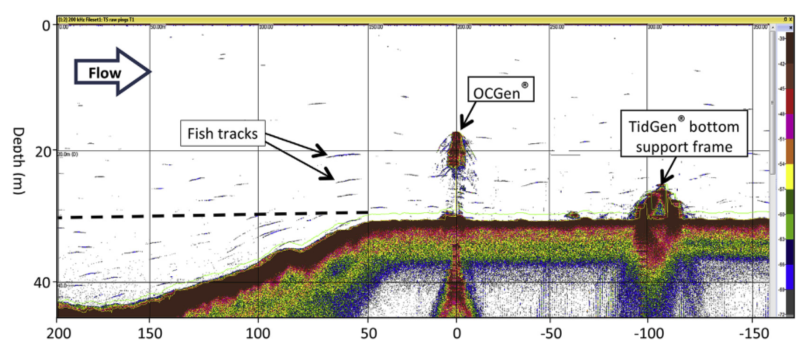


Fig. 3. One mobile transect over the OCGen® and the TidGen® bottom support frame during a flood tide. Fish tracks below the dashed line were excluded from analysis to ensure equal amounts of water sampled during the length of one transect.

Findings

- Distribution
  - Fish shoal around turbines
  - Attraction effect, may use for protection and feeding
  - Tidal effects with abundance inversely related to water velocity

Nemeth et al. 2014

Findings

- Interactions and behavior
  - There are interactions
  - Fish can avoid turbines
  - Probabilities of fish encountering the MHK device based on month, diel condition and tidal stage
  - Fewer interactions when turbine spinning
  - Schools react farther away than individuals
  - Turbine entry higher during night
  - No evidence of passage delay for migrators
  - No obvious injuries for fish passing through turbine

Flume studies

- Scaled-down experiments to inform in situ studies
  - Force fish near/through turbine, observe reactions
  - Results:
    - Avoidance common
    - Harm and mortality low:
      - Depends on:
        - » Species
        - » Age
        - » Entry angle
        - » Turbine characteristics

Schweizer et al. 2012

Figure 2. Investigator measuring flow velocities near location of larval fish insertion point.

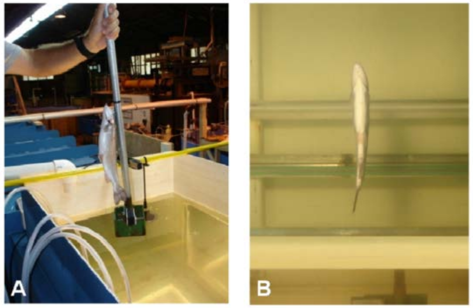


Figure 2-4
Rainbow Trout Being Placed in Test Tank (A) and Positioned Prior to Strike By Blade Moving from Right To Left in (B)

EPRI 2011

Simulation modeling

- Few collisions, avoidance
- Predictions > observations
- Blade strikes and mortality:
  - Less harsh than dam turbines
  - Mortality low
  - Strikes depend on:
    - Water velocity
    - Water clarity
    - Turbine type
    - Fish species
    - Fish size and blade width
    - Entry location
    - Entry angle

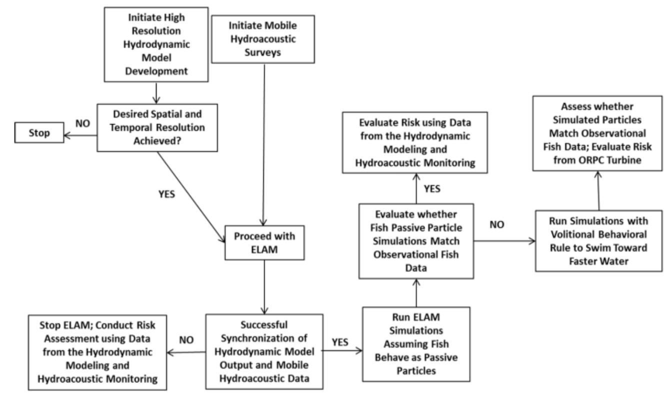
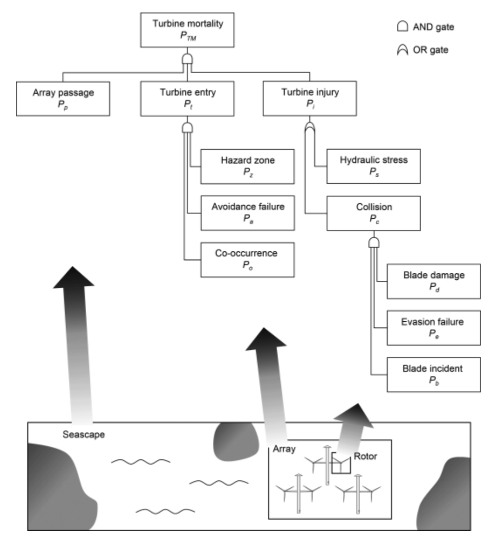


Figure 6 Conceptual model of ELAM analysis. This proposed work effort will evaluate only "direct" response behaviors to hydrodynamics. Grippo et al. 2017



Hammar et al. 2015

Fig 1. The generic collision risk model described as a fault tree diagram.

Future research areas

- Monitoring systems
- Effects on mass migration (smolts)
- Near field events (<10 m)
- Night time events
- Effects of lights for monitoring
- Identifying collision vs. near-miss
- Direct blade strike effects
- Condition of fish passing through turbine
- Automated analyses
- Relationships between turbine characteristics and fish behavior
- Multiple deployments
- Effects of attraction effects for other animals

Plug ’n’ Play
Marine Mammal Monitoring Platform

Douglas Gillespie[a], Mike Oswald[a], Gordon Hastie[a], Laura Palmer[a], Carol Sparling[b]

[a] Sea Mammal Research Unit, University of St Andrews, Scotland

[b] SMRU Consulting, St Andrews, Scotland

Sea Mammal Research Unit

University of St Andrews

Background

- Addresses the need for persistent monitoring of fine scale behaviour in the immediate vicinity of TT's.

If you're interested in very rare events, then you need to monitor for a very long time. i.e. if you want to show that there is < 1 collision per year, you'd better monitor for > 1 year !

3D tracking in a harsh, dark and turbulent environment

- Active Multibeam Sonar
  - Detects and tracks both seals and cetaceans
- Passive Acoustics
  - Provides species id and tracking of small cetaceans
- Cameras
  - Really see what's going on around the blades

- Cabled System
  - Power and comms from turbine infrastructure provides unlimited deployment duration

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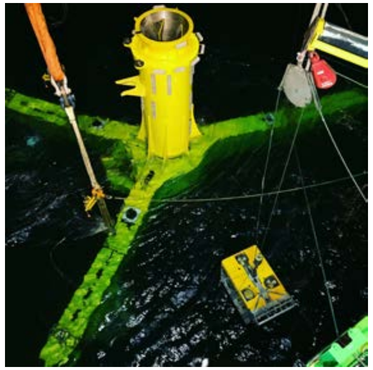
University of St Andrews

Current Meygen System (Pentland Firth)

- 12 hydrophones and two cameras mounted on turbine base
- Two Tritech Gemini Multibeam sonars on remote platform
- All deployed in one ‘lump’,
  - Remote platform dry cabled to turbine,
  - hanging off side during deployment,
  - then craned to final location.



- PAM, AAM and Cameras all connected to single junction box which connected into turbine connection system for power + comms

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Meygen Life History

- Deployed October 2016
- Problem with power from turbine
- Power problem rectified October 2017
- PAM survived the year at sea, AAM and camera connectors corroded
- Considerable biofouling on all systems
- Continuous PAM data collection since Oct’ 17

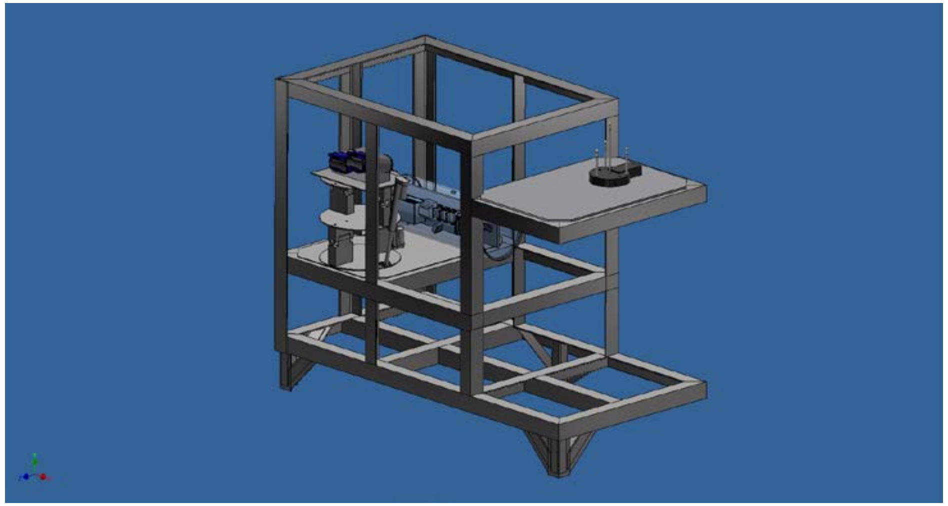
Sea Mammal Research Unit

Lessons Learned from Meygen

- Mounting on Turbine presented significant logistical problems and a lot of engagement from turbine engineers
- Unable to retrieve equipment for repair / cleaning
- May not be practical on future turbines (e.g. monopoles)
- ROV connectors v. expensive, but worth it !
- Will always require considerable company engagement
  - They will always want to be responsible for any vessel ops around their kit
  - Will still need to tap off their power and comms

The NERC PnP platform

- Single remote station to install 30m from turbine
- Two Tritech Gemini active sonars mounted on tilt / roll
  - Provides range and horizontal bearing to all species, relatively poor vertical angle
- Single Tetrahedral cluster of high frequency hydrophones
  - Provides horizontal and vertical bearings to small cetaceans, no range data
- No Cameras (too far from turbine)
- UVC light system to reduce biofouling of sonars and PAM
- Junction box for power & comms distribution & turbine connection
- Frame – "about the size of a large desk"
- Power 80W
- Data bandwidth < 100Mbps
- One PC on shore for data acquisition



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Almost
Plug n Play

- Cable to turbine will always depend on the turbine / details of installation, so is out of scope. Will always need to adapt final connector to turbine either with a different connector, or a 'pig tail' adapter.
- Power availability may vary (e.g. 48V DC, 220V AC). Not a significant problem, space is available in junction box for any additional power converters.
- Copper or Fibre Ethernet connection. Has to remain flexible to suit different turbine manufacturers preferences / cable lengths. Changes will require changing one face plate connector and one internal component
- All else can remain the same

Summary

- Provides flexible monitoring platform for seals and small cetaceans
- Requires minimum modification for specific turbine installations
- Could be differently configured for different species priorities
- Hoping to install at Meygen site autumn 2019
- Can discuss alternative configurations for different species mix

Questions ?

Development of the Adaptable Monitoring Package: Past, Present, and Future

James Joslin, Emma Cotter, Paul Murphy, Paul Gibbs, Andy Stewart, and Brian Polagye

February, 2019

University of Washington

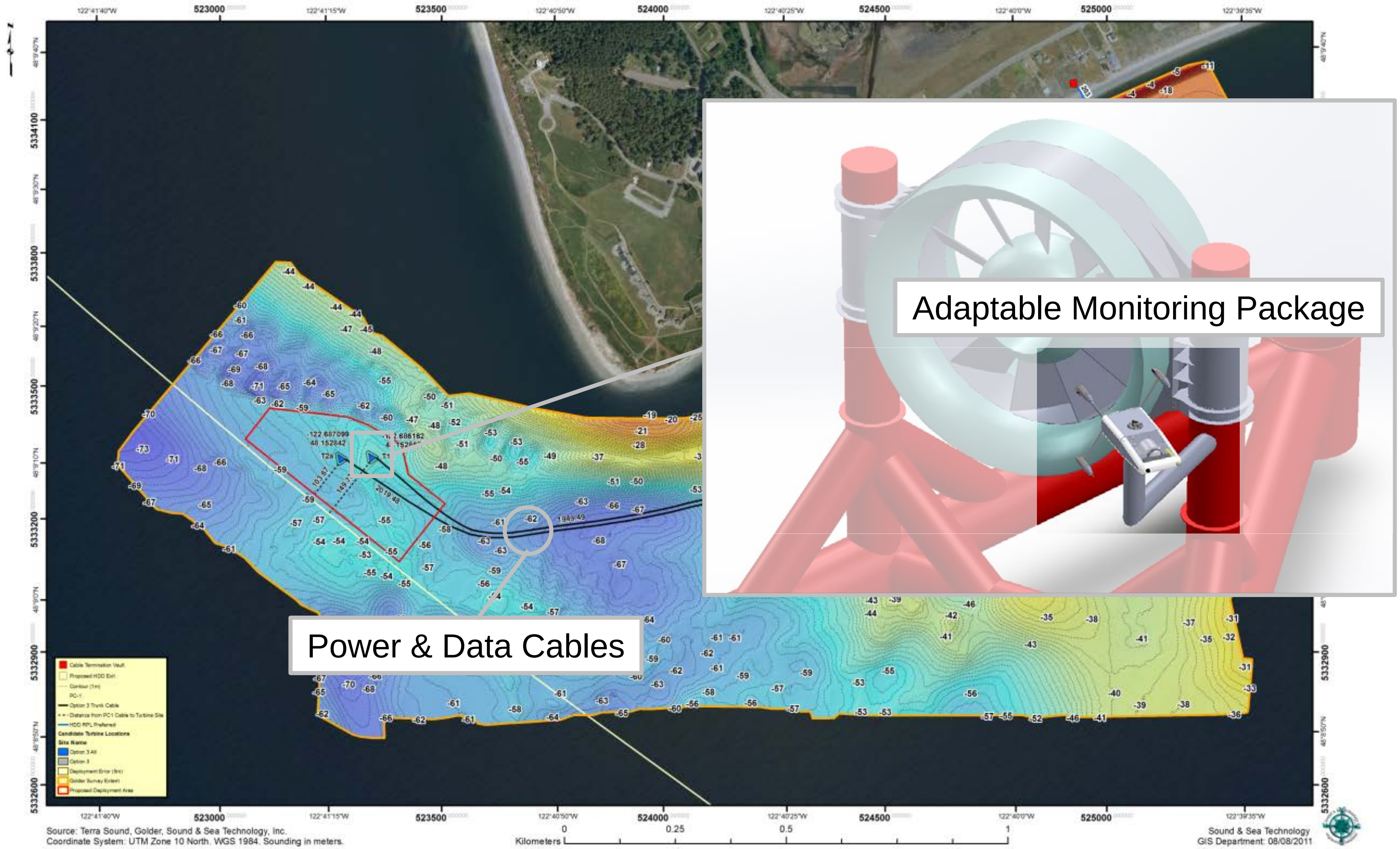
PMEC
Pacific Marine Energy Center

UNIVERSITY OF ALASKA FAIRBANKS

Oregon State University

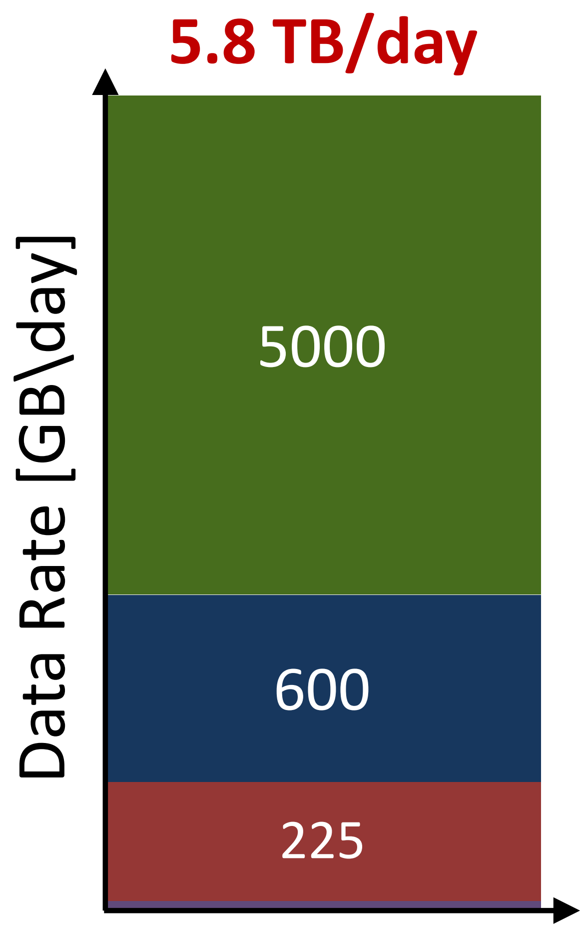
UNIVERSITY of WASHINGTON

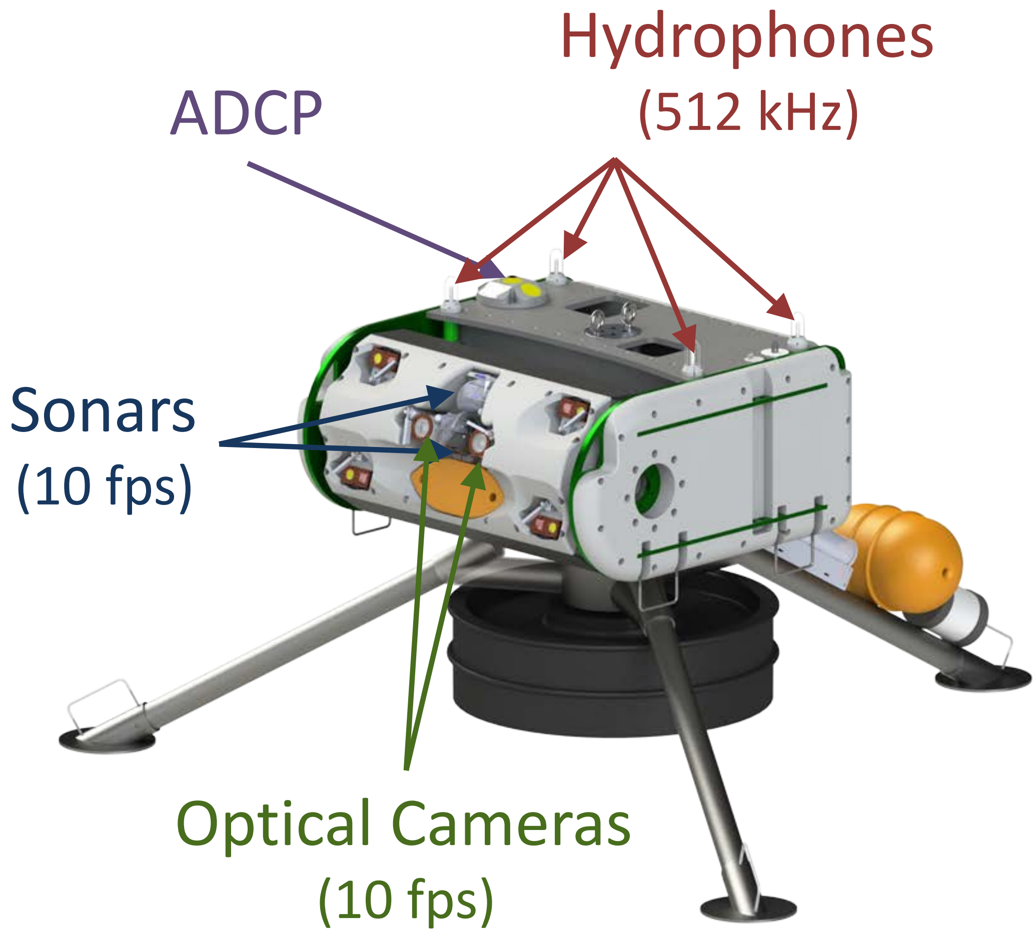
Concept Origin



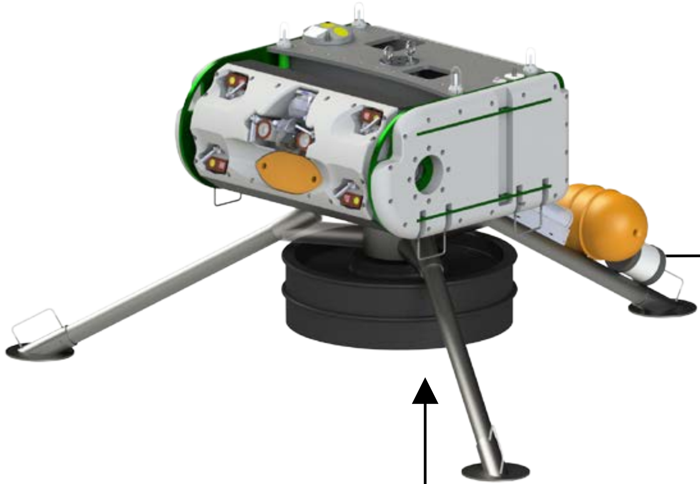
Map Credit: Sound & Sea Technology

Data Management





Generations of Development



Sensor Synchronization and Control

Sensor A | Sensor B | Sensor C

Real-Time Processing Modules

Target Tracking | Target Classification | Situational Awareness

"First Generation"

Common power and data connectivity

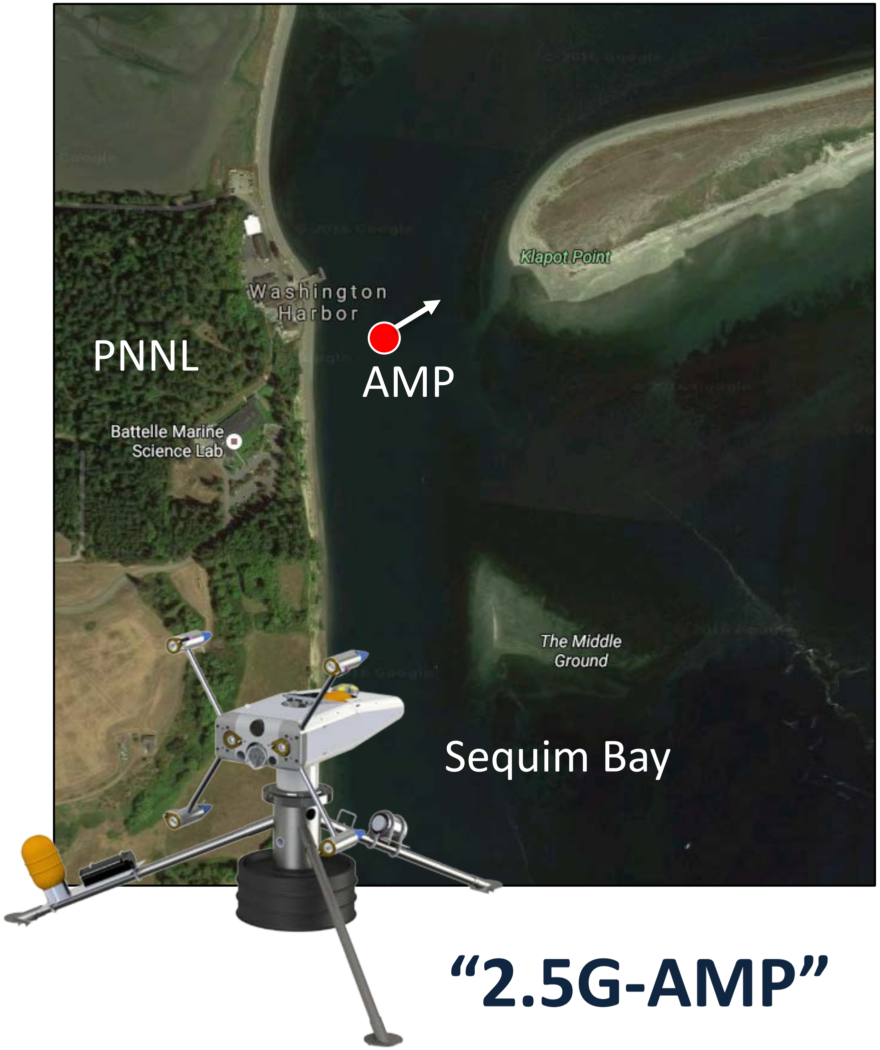
"Second Generation"

Common software framework

"Third Generation"

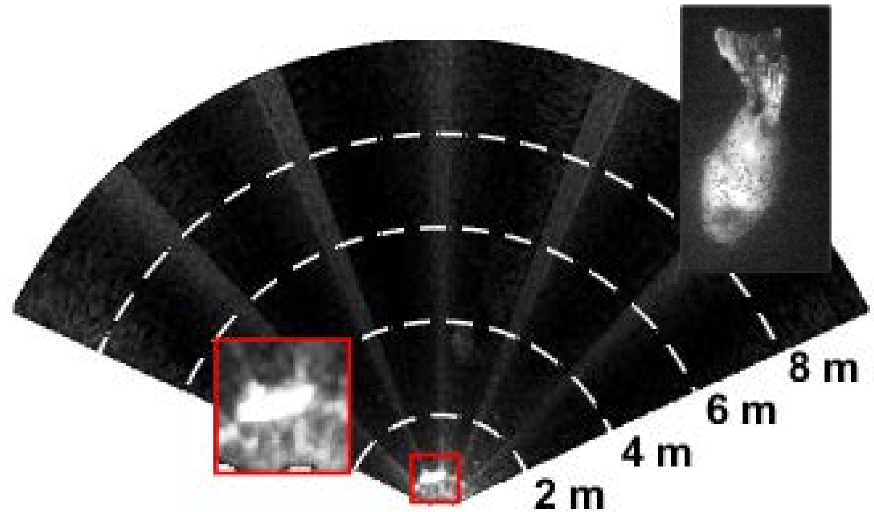
Real-time control of sensors and data

Past Testing: PNNL Marine Science Lab

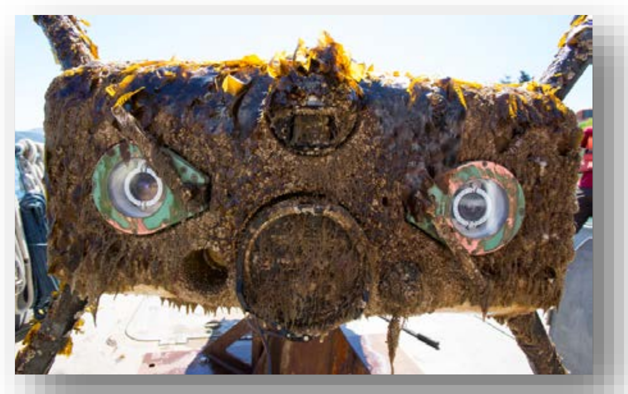


"2.5G-AMP"

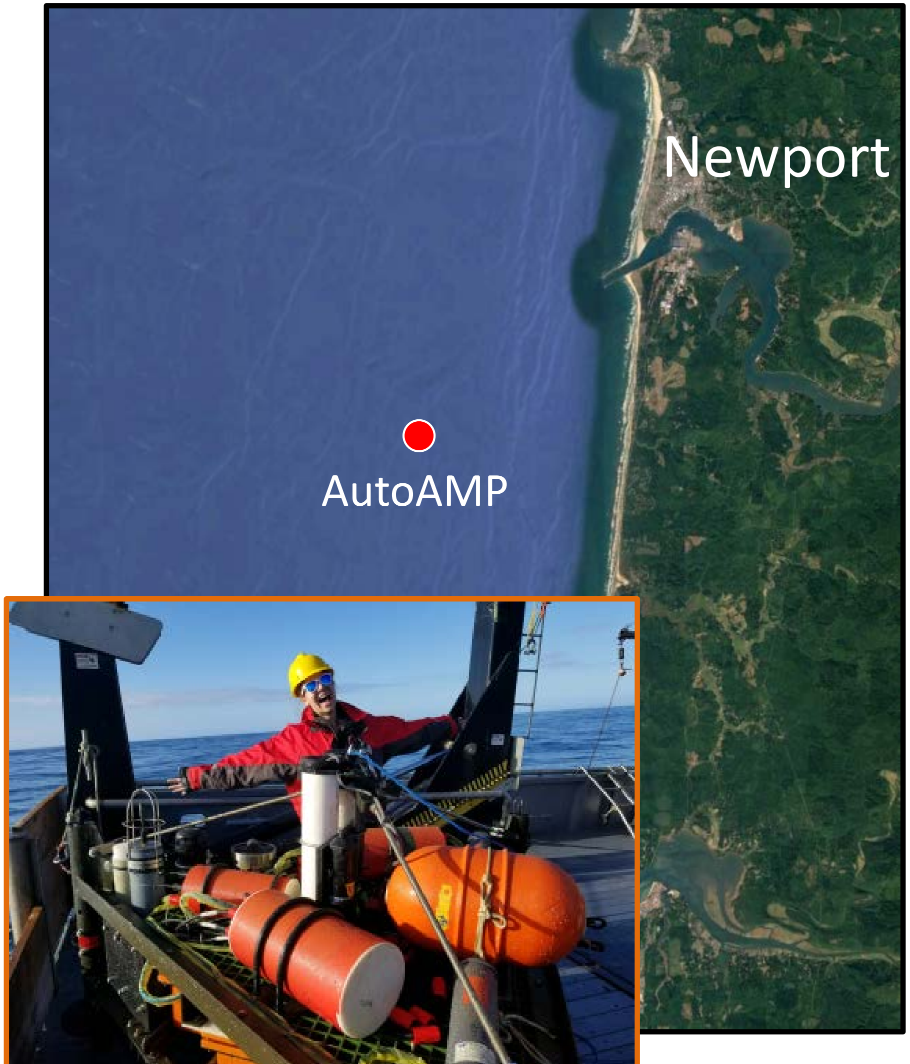
Map Credit: Google



Detect targets of interest in non-intrusive sensor data and trigger acquisition and archiving



Past Testing: Oregon Wave Test Site



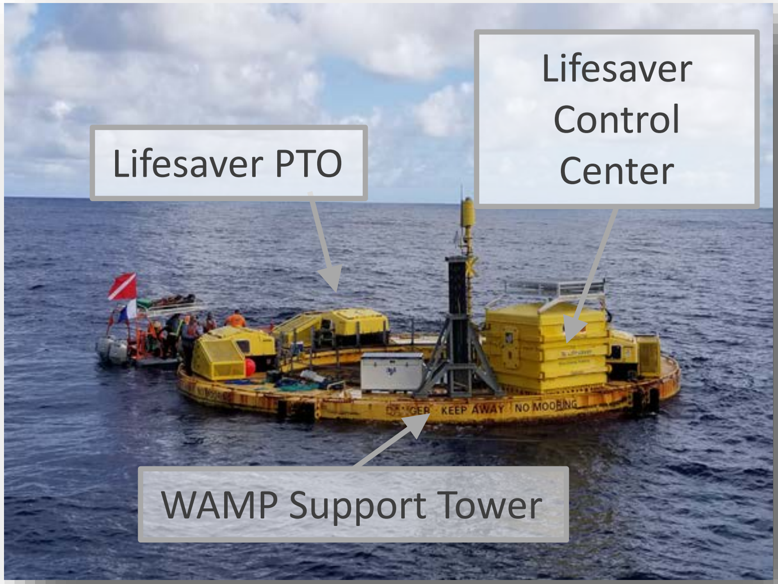
Map Credit: Google

"AutoAMP" (2G)

+ On-board sensor control and data acquisition
+ On-board power (batteries)
+ Automatic startup and shutdown on a duty cycle

Video Credit: CoRIS, Oregon State University

Present: WEC Integration



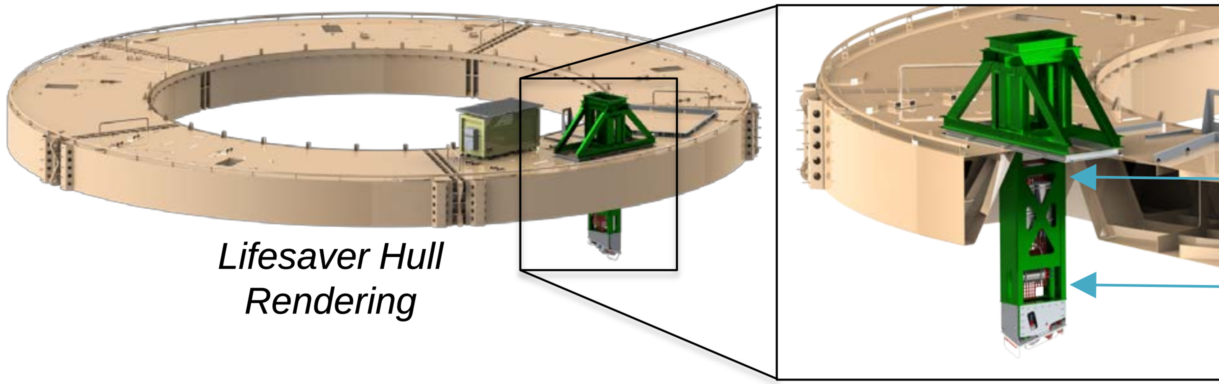
Lifesaver (WAMP Retracted)

Equipment Detail (WAMP Deployed)

Wave-powered Adaptable Monitoring Package ("WAMP")

- Persistent, integrated environmental sensing system and UUV recharge capability
- Storage-backed microgrid with wave (primary) and solar (backup) energy generation
- Real-time detection and classification of data streams on board WEC

WAMP Instrumentation



Lifesaver Hull Rendering

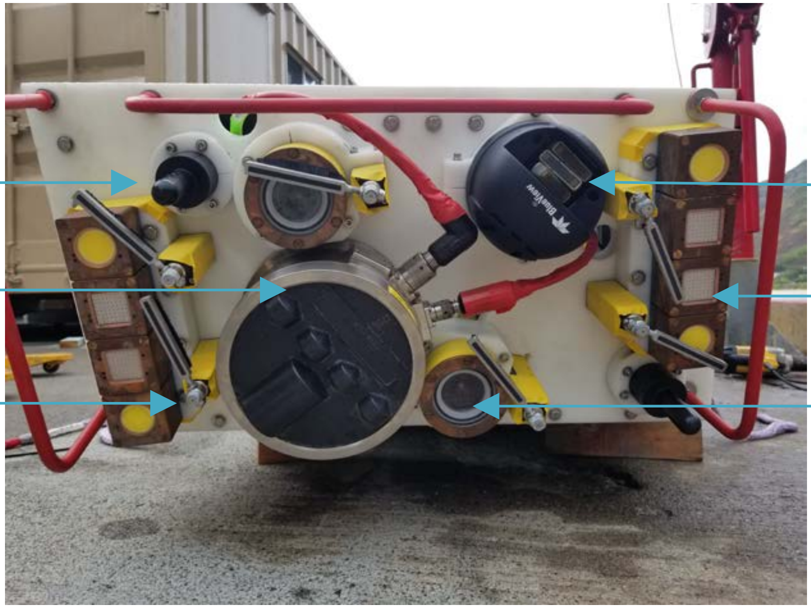
AMP Instrument Control Bottles

Wibotic Wireless Power Transfer (UUV Recharge System)

Ocean Sonics icListen Hydrophone

Kongsberg M3 Multibeam Sonar

Zebra Tech Hydrowipers



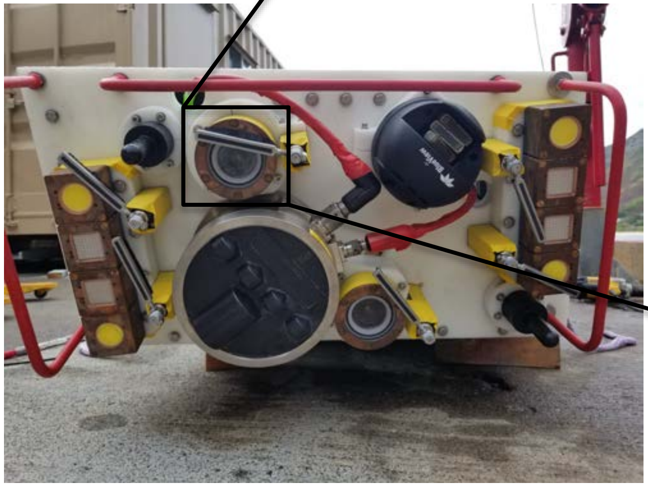
BlueView M900/2250 Acoustical Camera

Red/White LED LIghts

Stereo Optical Cameras

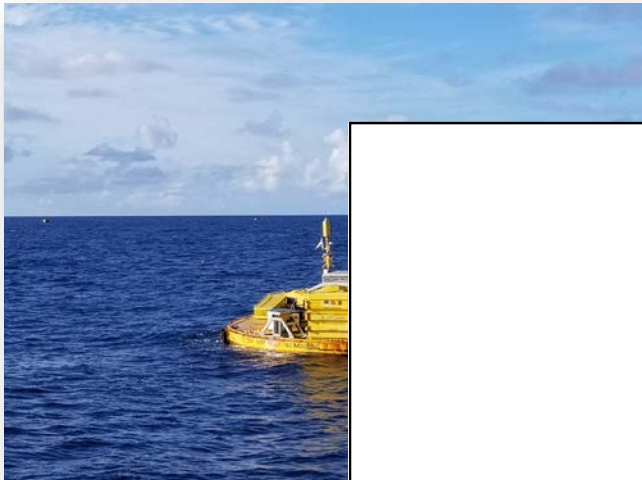
WAMP Instrument Head

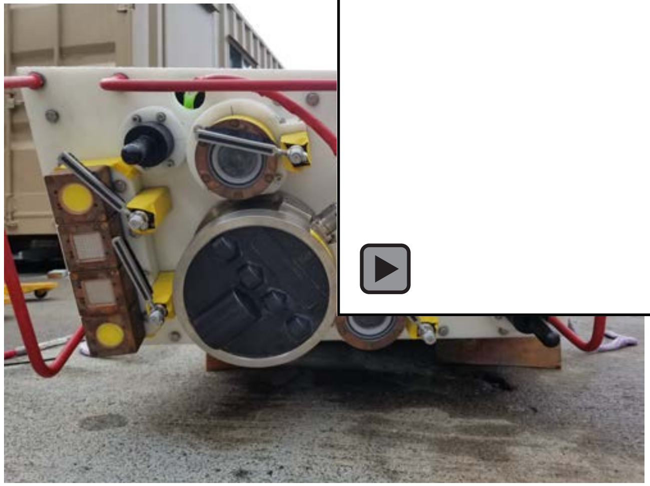
WAMP Optical Data

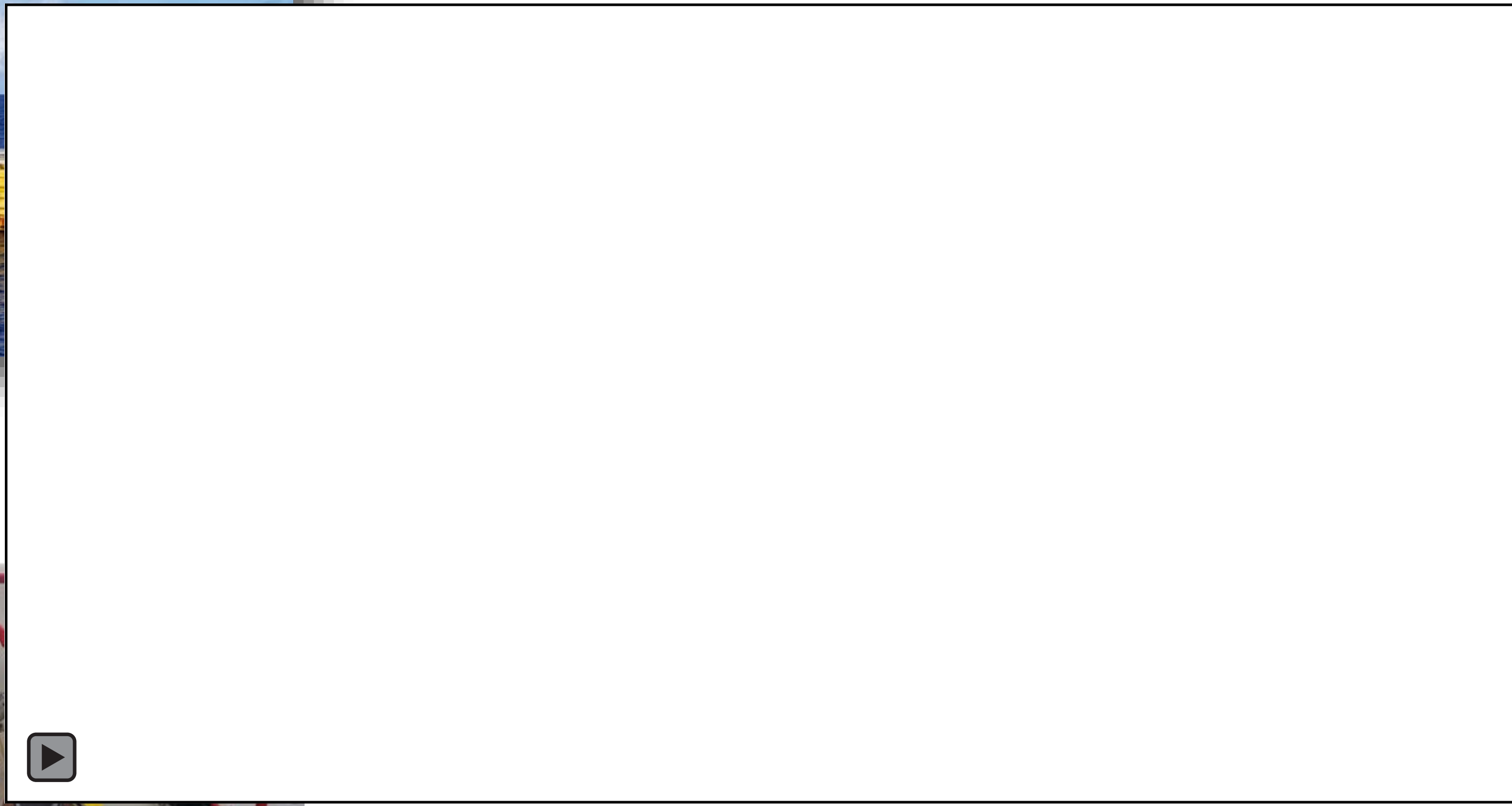


WAMP Optical Example with Fish

WAMP Acoustic Data



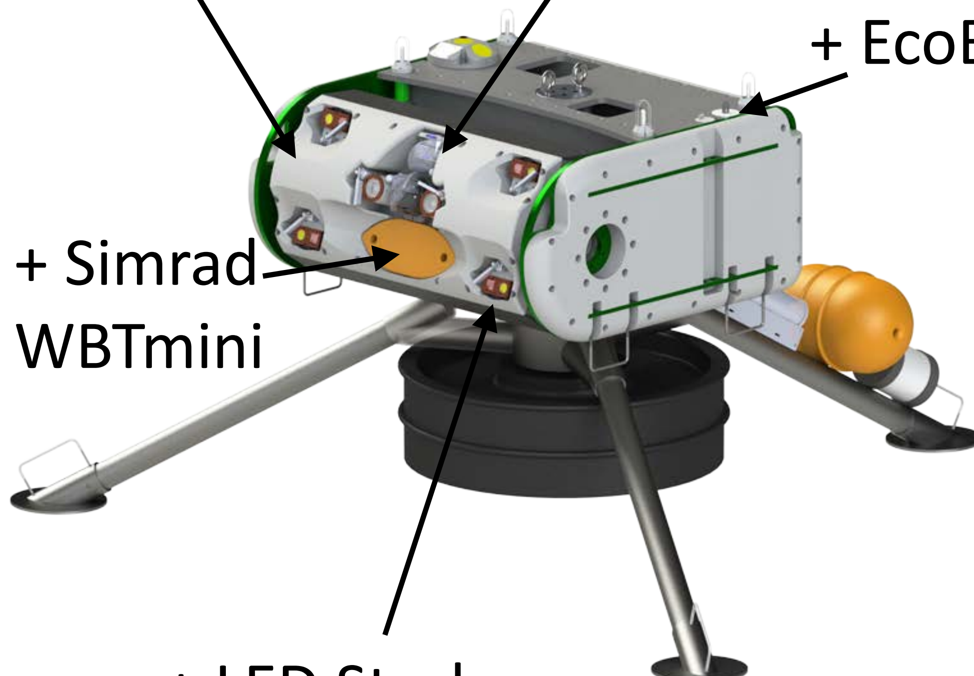




WAMP BlueView Example

Present: 3G-AMP

Deployment in January 2019

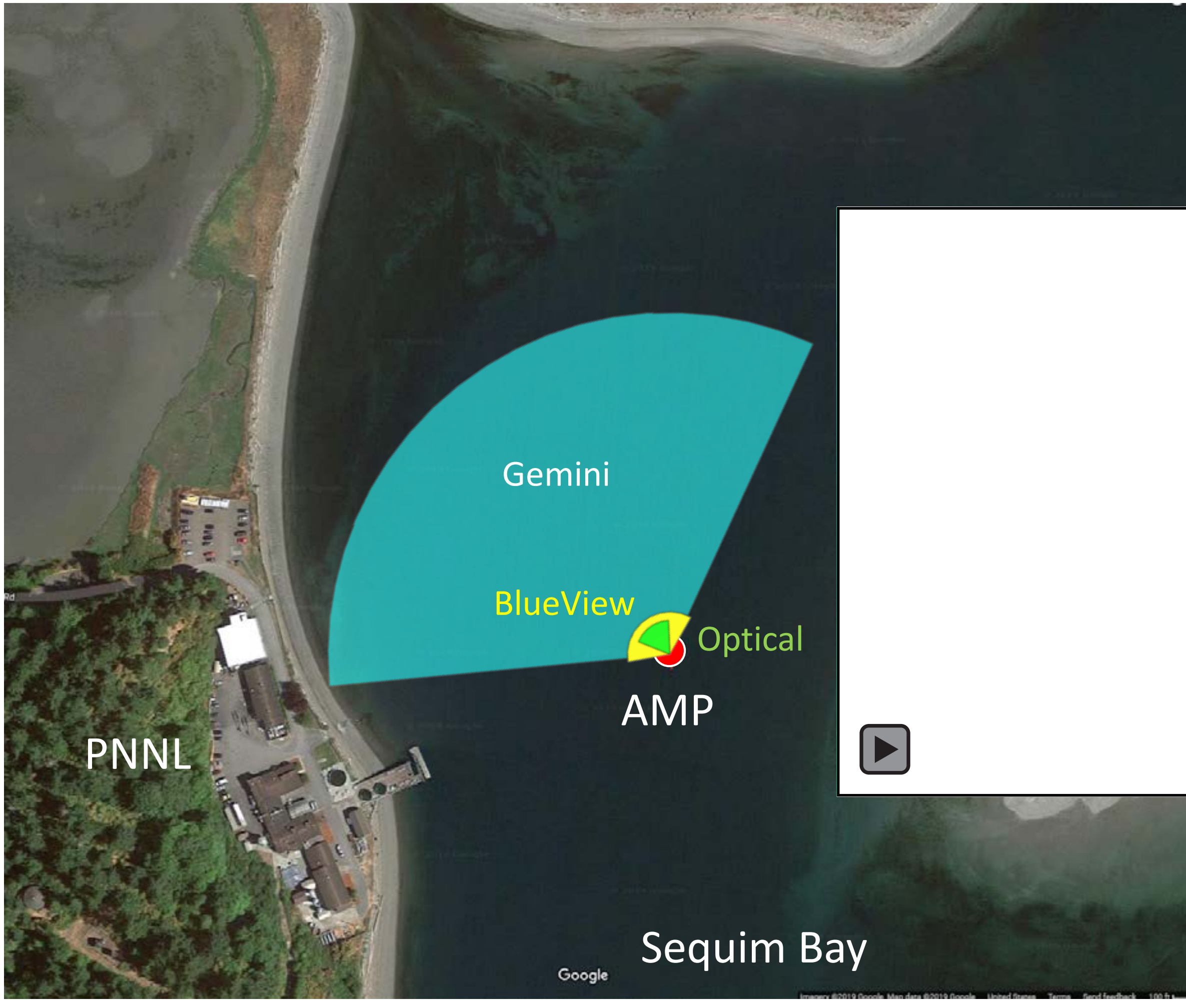


3G-AMP at MSL

Map Credit: Google

Current Deployment Location

3G-AMP at MSL

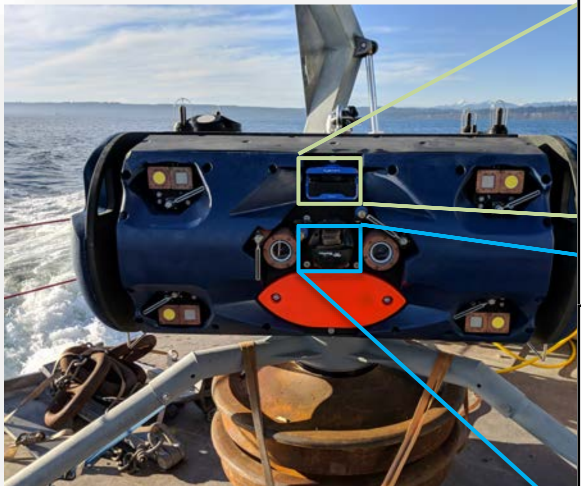


Map Credit: Google

Diver Inspection

Current Deployment Location

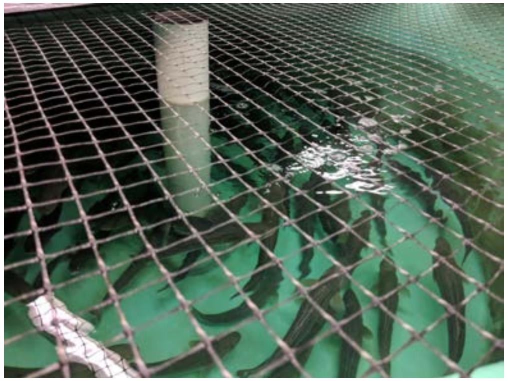
3G-AMP Acoustic Data



3G-AMP Collision Risk Study

- Two phase study to compare methods for detecting and tracking tagged fish through Sequim Bay channel
- Collaboration with PNNL to evaluate JSATS tags and hydrophone array along with 3G-AMP instruments

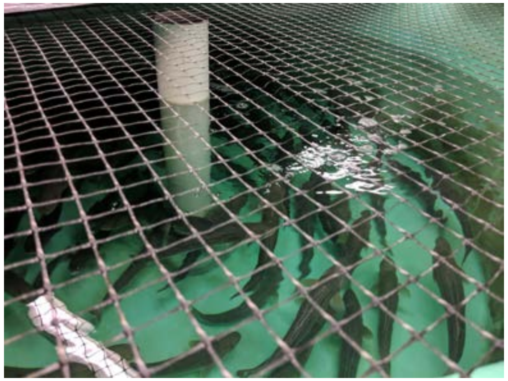
Current Deployment Location



Tagged Fish for Release

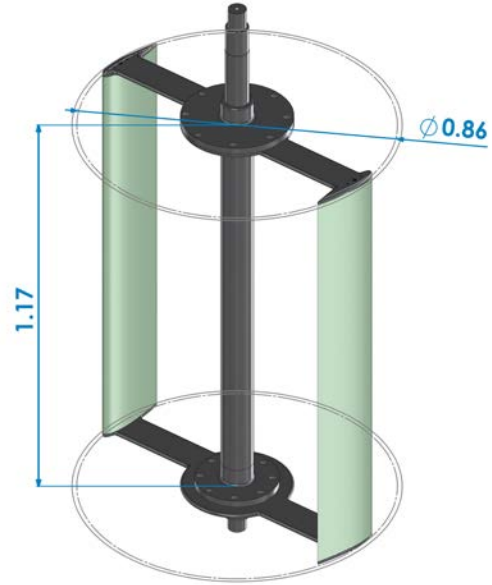
3G-AMP Collision Risk Study

Current Deployment Location



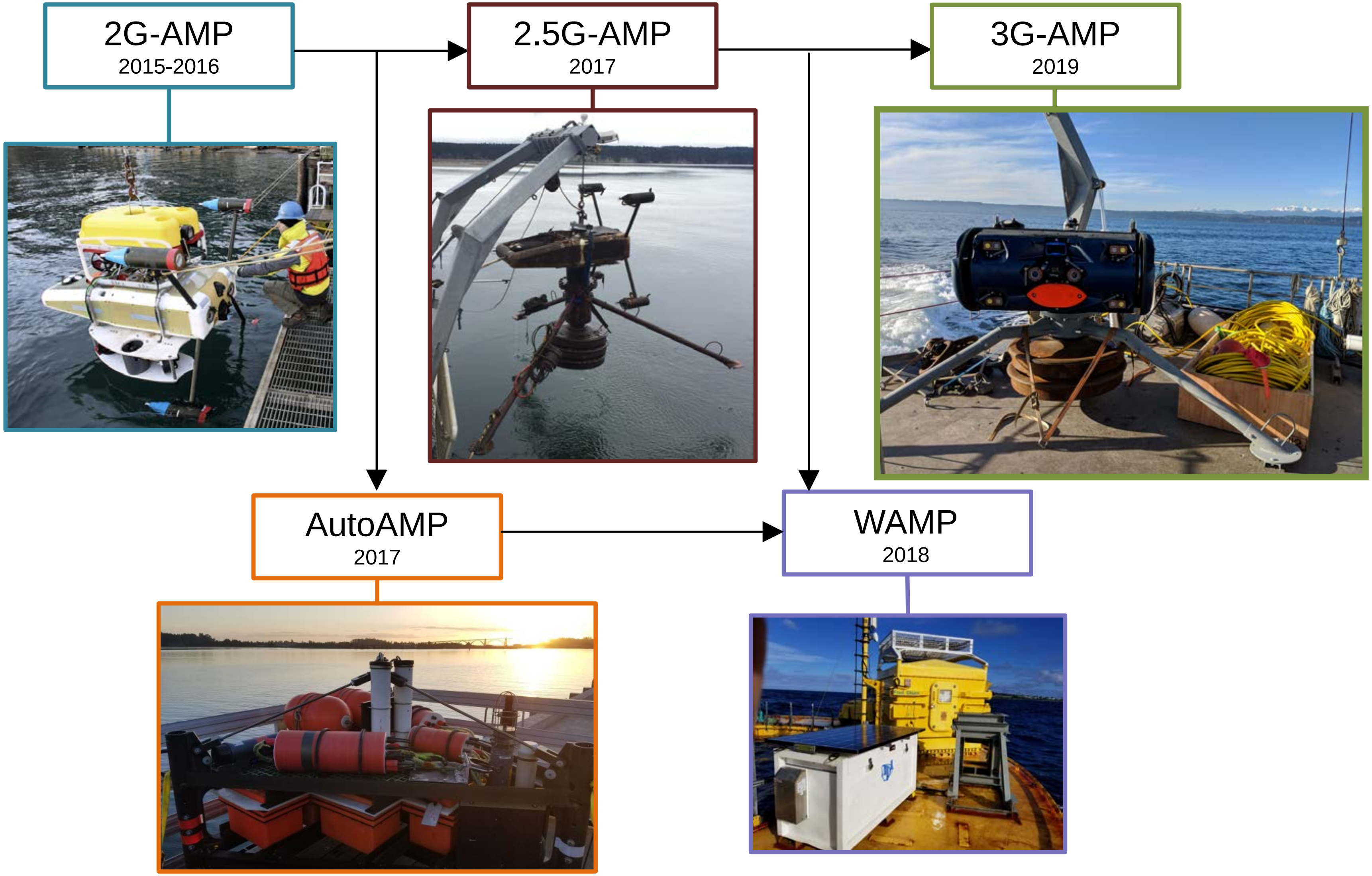
Tagged Fish for Release

- Second phase to evaluate collision risk in the with small scale cross-flow turbines
- Augment AMP instrumentation during turbine deployment to track tagged fish



Cross-flow Turbine Rendering

AMP Development



Autonomous Battery-powered

Autonomous Wave-powered

Acknowledgements

The AMP development and testing presented here would not have been possible without the contributions of Sarah Henkel's and Geoff Hollinger's research groups at Oregon State University, Pat Cross at the University of Hawaii, Even Hjetland of Fred.Olsen, the crew of R/V *Jack Robertson*, the crew of R/V *Pacific Storm*, the crew at Sea Engineering, and the field operations team of John Vavrinec, Sue Southard, Kate Hall, and Garrett Staines at Pacific Northwest National Laboratory's Marine Science Lab.

This work is based on funding received from the US Department of Energy and US Department of Defense. Emma Cotter is supported by a National Science Foundation Graduate Research Fellowship.

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Oregon State University

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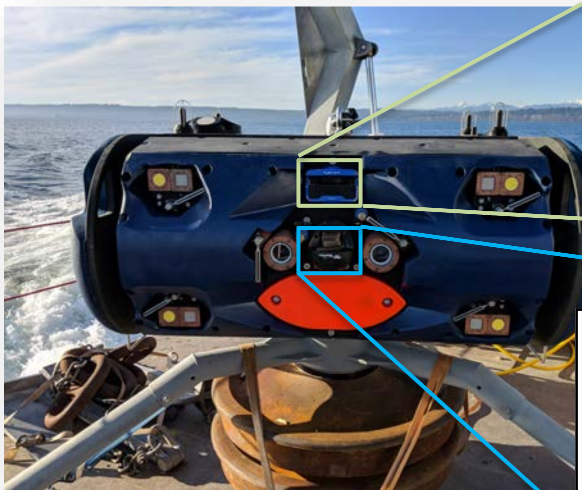
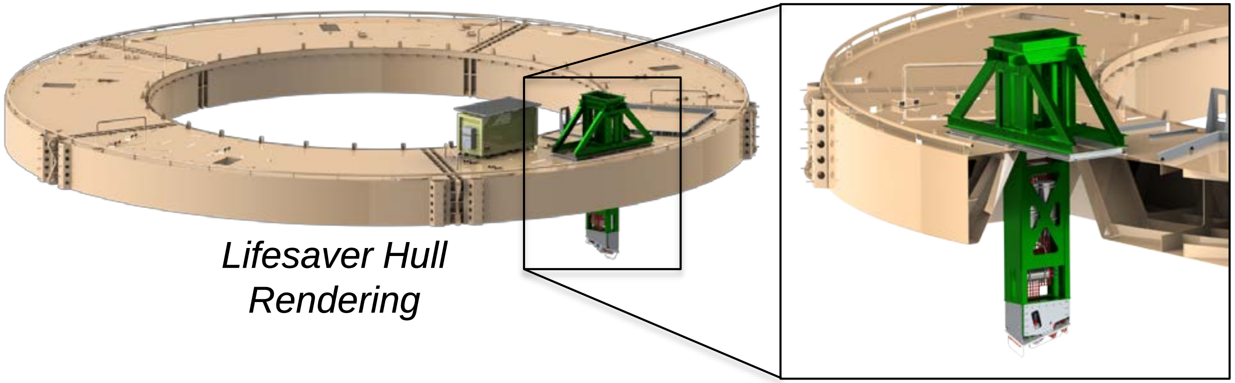
3G-AMP Acoustic Data



MSL AMP Optical Data

AMP Optical Example

WAMP Inspection



Lifesaver Hull Rendering

Go-Pro Footage from Dec. 2018

FORCE

FORCE: Fundy Advanced Sensor Technology (FAST) Program

Daniel J. Hasselman, *Science Director*
Fundy Ocean Research Center for Energy
www.fundyforce.ca

Overview

- Overview FAST Program
- Sensor Development Plan 2020
  - ‘Path 2020’

Overview

- Overview FAST Program
- Sensor Development Plan 2020
  - ‘Path 2020’

Fundy Advanced Sensor Technology Program

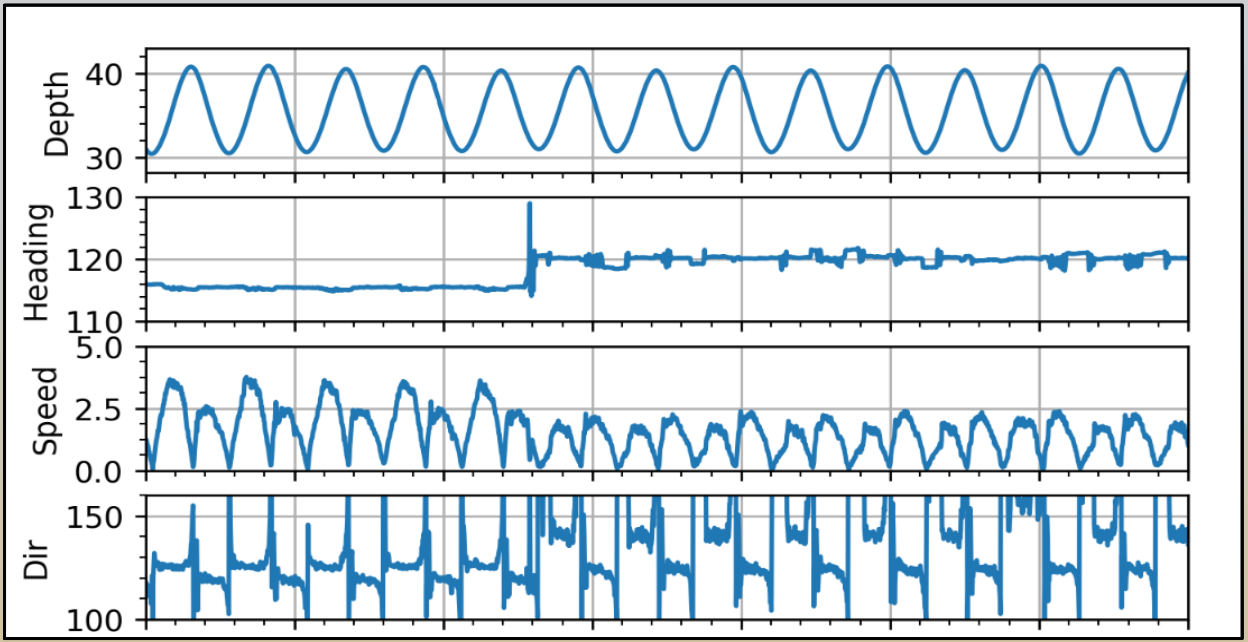
- Onshore and subsea (autonomous and cabled) instrument platforms
- Onshore:
  - X-Band radar (wave/surface currents; enhanced modelling)
  - weather station (hi-res imagery and environmental variables)
  - real-time tidal gauge (web-enabled - FORCE Data Dashboard)

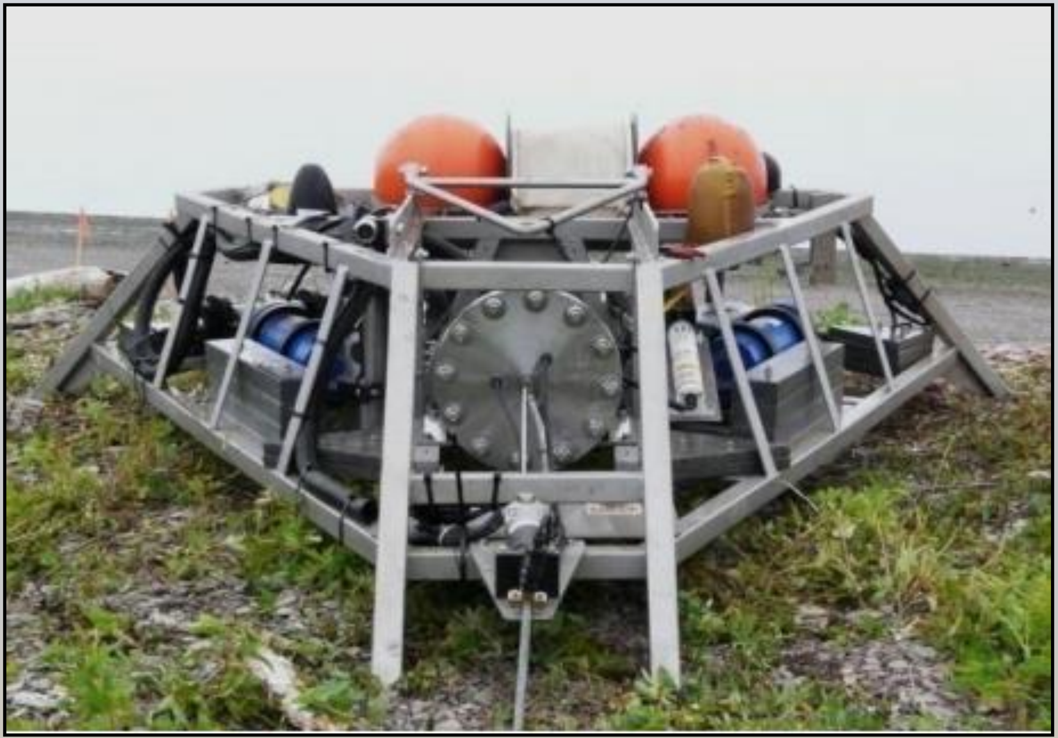
Fundy Advanced Sensor Technology Program

- Subsea platforms:
  - FAST-1 (autonomous)
  - Vectron - remotely measure turbulence in mid-water column

Fundy Advanced Sensor Technology Program

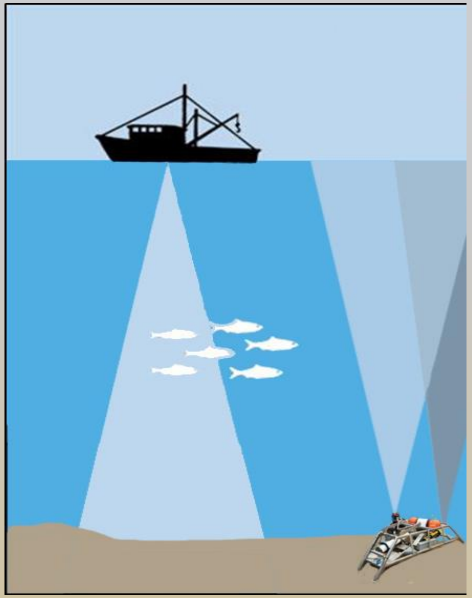
- FAST-2 (autonomous; site characterization)
  - ADCP
  - CTD, DO
  - fish tag receiver
  - subsea camera, light
  - multiplexer and termination canister





Fundy Advanced Sensor Technology Program

- FAST-3 (autonomous)
  - ADCP (Acoustic Doppler Current Profiler)
  - AZFP (narrowband single beam echosounder)
  - WBAT (broadband split beam echosounder)
- Fish Finders project:
  - collaboration with Dr. Haley Viehman (Echoview)
  - mobile fish surveys (EK80) vs. FAST-3 instruments
  - determine spatial and temporal representative range (i.e., optimal distribution of sensors required to resolve the variability in fish distribution) (Horne and Jacques 2018)



Fundy Advanced Sensor Technology Program

- FAST-EMS (Environmental Monitoring System)
  - cabled platform - real time data
  - directional sensors, ADCP
  - Gemini imaging sonar with dynamic mount (pan/tilt)
  - Scuplin subsea camera
  - icListen hydrophones
  - multiplexer
  - termination canister

Overview

- Overview FAST Program
- Sensor Development Plan 2020
  - ‘Path 2020’

- Sensor Development Plan 2020 -
The road to regulatory certainty

- Turbine developers have economic incentive to deploy at FORCE until end of 2020 (feed in tariff: $0.53/kwh)

- Regulatory issue:
  - must detect fish/marine mammals and their interactions with turbines
  - must provide near real-time monitoring results

- Needed:
  - Integrated, performance-tested sensor package accepted by regulators
  - Proven, robust cabled platform and related deployment capabilities
  - Automated data processing algorithms/software for analytics

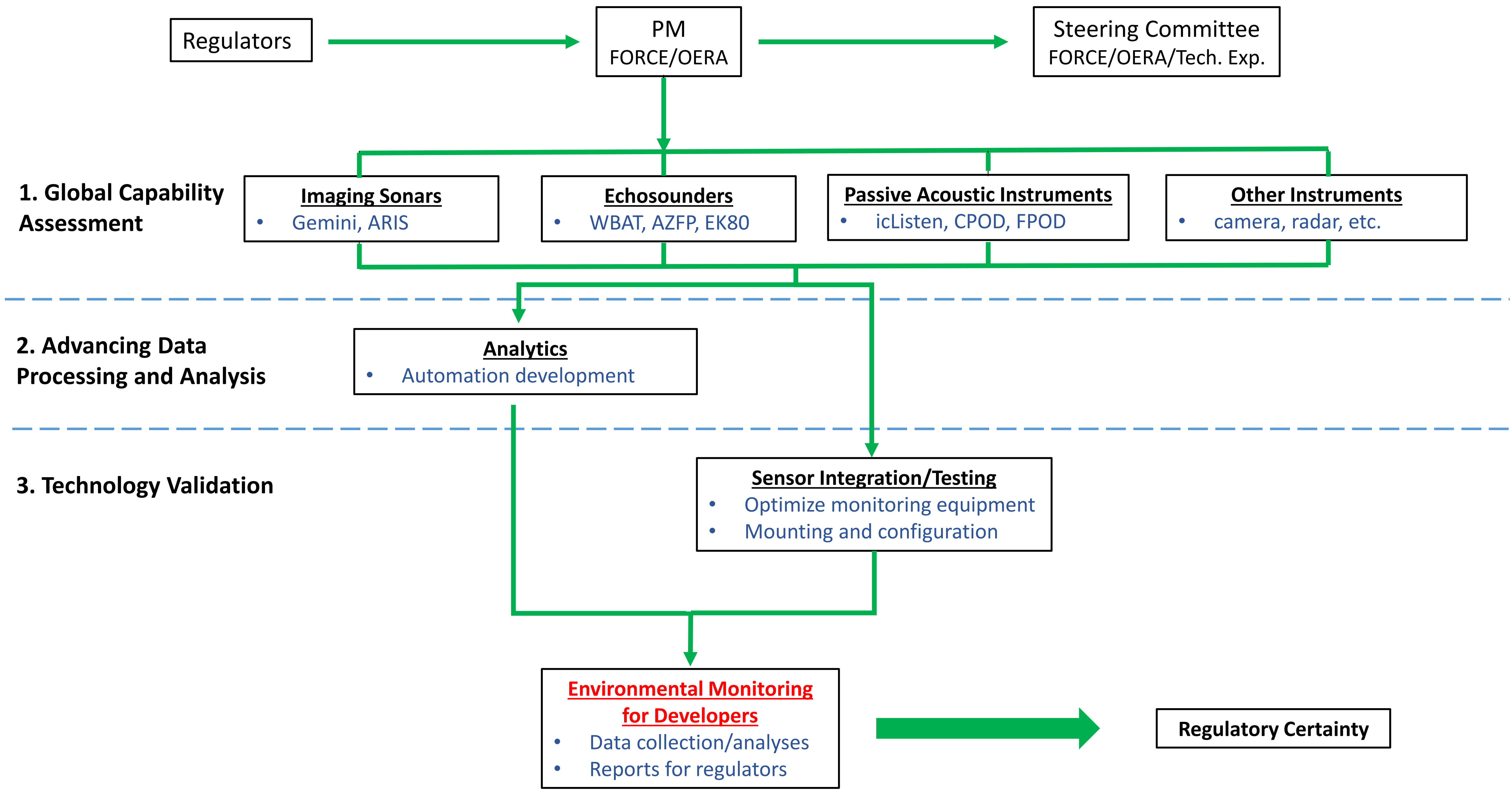
- Sensor Development Plan 2020 - A multiphased approach (FORCE/OERA/NSDEM)

- Three overlapping project paths:
  1. **Global Capability Assessment**: operational parameters and limitations of environmental monitoring sensors:
     - echosounders, imaging sonars and passive acoustic devices, others?
     - incorporated into Chapter 4 of Annex IV State of Science Report 2020
  2. Development of real time **Data Processing and Automation** tools:
     - collaborations between software developers (Echoview) and academia (Computer Science)
     - data is available to begin this work immediately
  3. Phased **Technology Validation** of 'best-in-class' instruments
     - controlled testing (Aquatron) and sensor integration
     - deployment in increasingly harsh real-world conditions on cabled platform

Advancing Environmental Monitoring Together

“Marine renewable energy developers, regulators, scientists, engineers, and ocean stakeholders must work together to achieve the common dual objectives of clean renewable energy and a healthy marine environment.”

-George W. Boehlert and Andrew B. Gill (2010)



Regulators
PM
FORCE/OERA
Steering Committee
FORCE/OERA/Tech. Exp.
1. Global Capability Assessment
Imaging Sonars
• Gemini, ARIS
Echosounders
• WBAT, AZFP, EK80
Passive Acoustic Instruments
• icListen, CPOD, FPOD
Other Instruments
• camera, radar, etc.
2. Advancing Data Processing and Analysis
Analytics
• Automation development
3. Technology Validation
Sensor Integration/Testing
• Optimize monitoring equipment
• Mounting and configuration
Environmental Monitoring for Developers
• Data collection/analyses
• Reports for regulators
Regulatory Certainty

Thank you

Dan Hasselman, *Science Director*
dan.Hasselman@fundyforce.ca

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-George W. Boehlert and Andrew B. Gill (2010)

FLOWBEC Integrated Monitoring Platform for Near-field Behavioural Measurements

Benjamin Williamson, Beth Scott
Ana Couto, James Chapman
Shaun Fraser, Vladimir Nikora
Philippe Blondel, Ian Davies

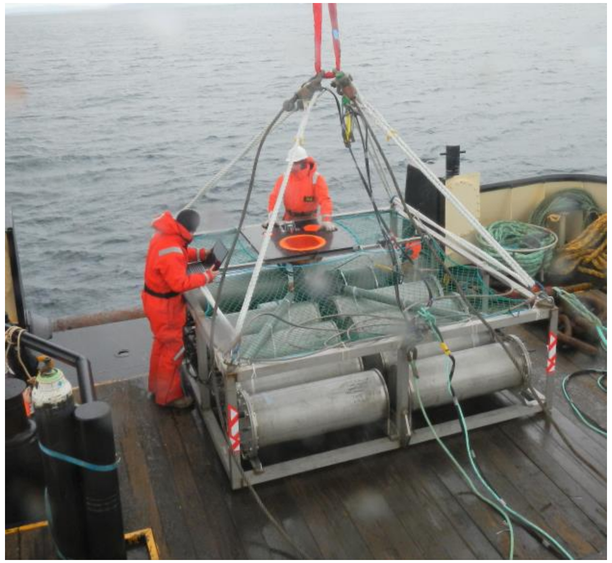
benjamin.williamson@uhi.ac.uk

NE/J004308/1, NE/J004200/1, NE/J004332/1, MREKE Internship
Innovate UK KTP / MeyGen, NE/N01765X/1, BEIS SEA

(Williamson et al., Oceanic Engineering, 2016)

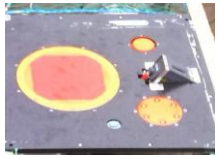
The FLOWBEC multi-sensor platform

Requirement: concurrent ecological (fish, bird and mammals) and physical data

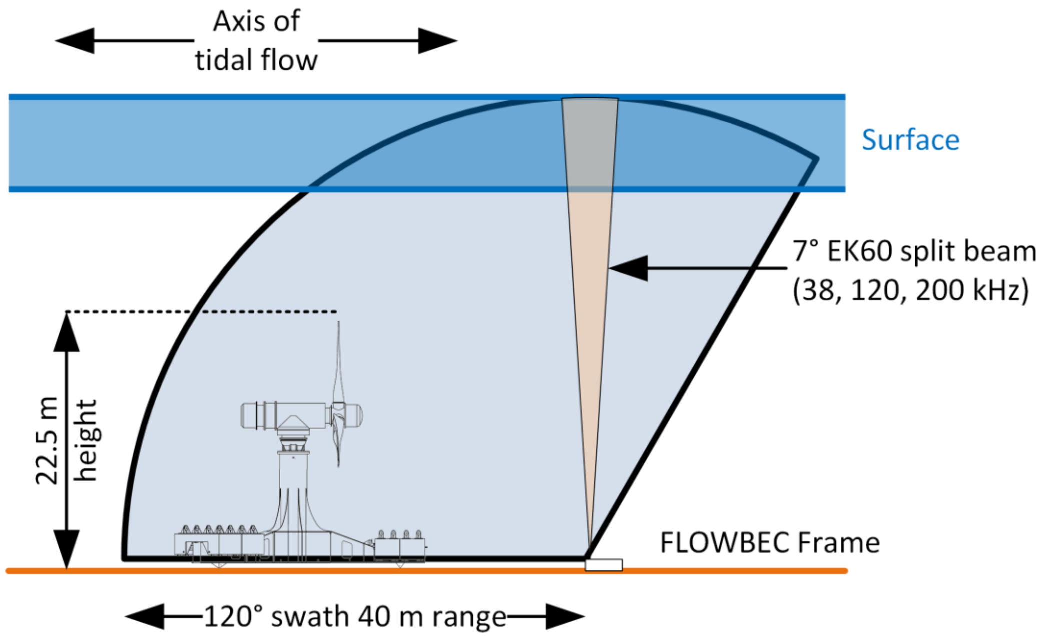


Hydrodynamics → ADV & ADCP


Animal distribution → EK60 echosounder



Nearfield behavior and interactions e.g., evasion → Multibeam echosounder



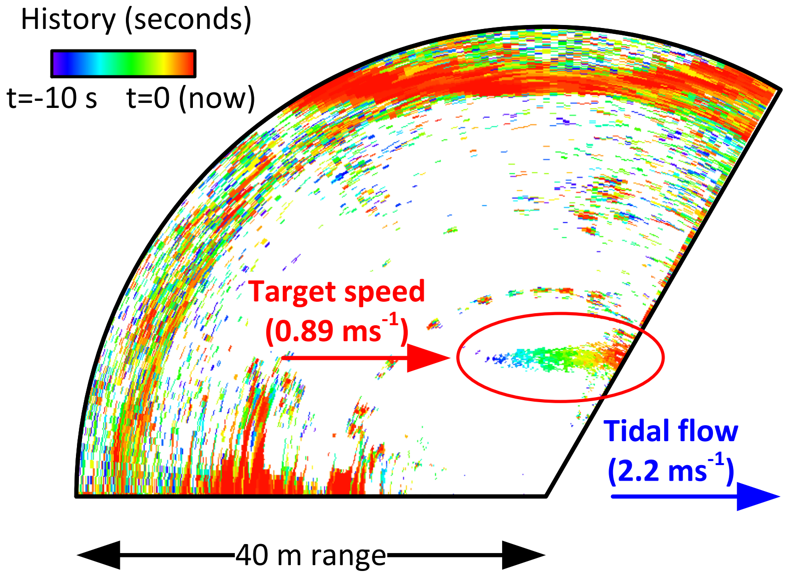
Fluorometer / turbidimeter

Camera

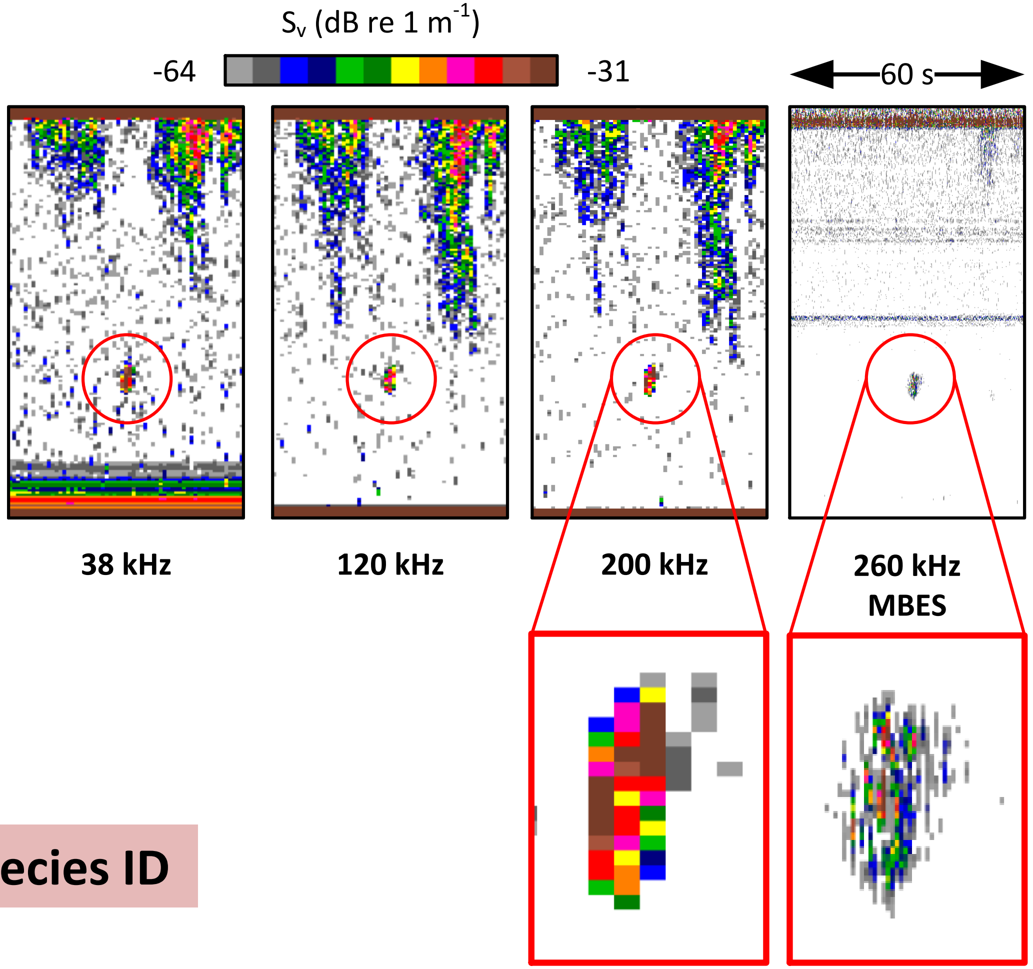
PAM

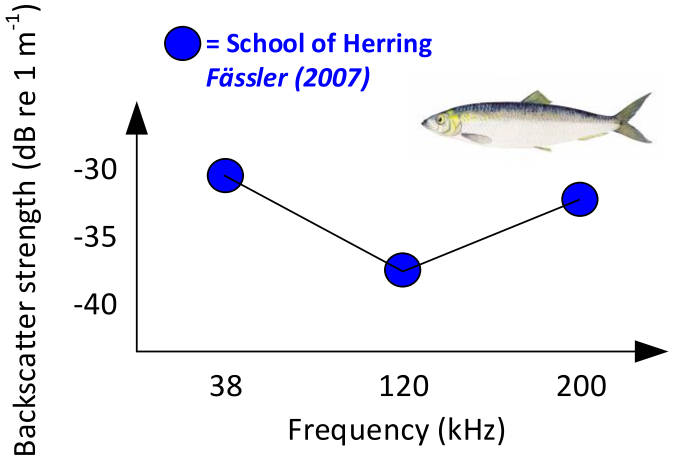
Co-registered datasets

Behaviour and interactions



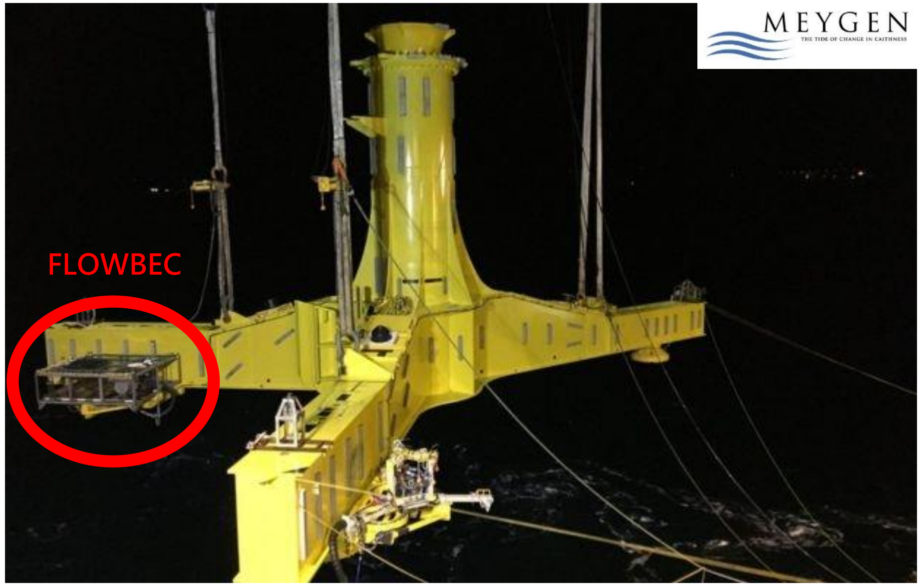
Morphology and turbulent covariates / predictors





Species ID

The FLOWBEC multi-sensor platform



Either battery powered

(before/after or control/impact studies…)

52.8 kWh batteries

2 week – 3 month deployment, depending on sensors

Rechargeable in 24-h neap window

Or cabled to a structure

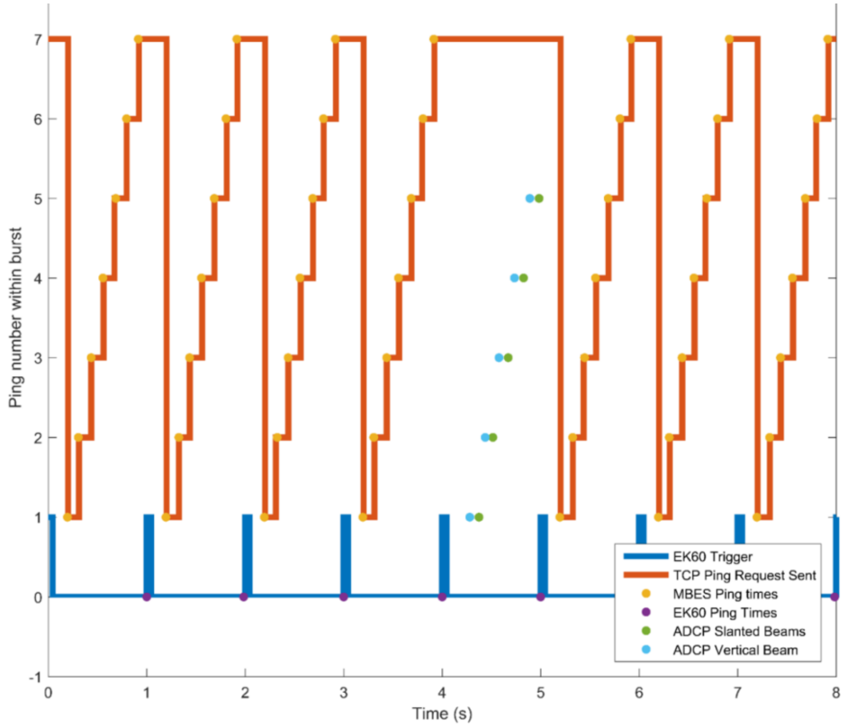
Realtime data

Longer endurance

Challenges overcome

Sensor integration:

- Concurrent operation of multiple sensors without interference
- Co-registration of targets across instruments
- Interleaved pings, flexible sampling schedules, e.g., focused bursts or triggering
- Alternative is duty-cycled instruments (missed data)



Field-proven robust platform for reliable data collection

Challenges overcome

Automated processing for animal detection in <u>all flow conditions</u>:

- Turbulence, entrained air, wakes compromise acoustic data
- Adaptive algorithm to preserve sensitivity across conditions *(Fraser et al., ASLO, 2017)*
- Alternative is false detections, or masked high energy periods (discarded data)
- Or manual processing (not realtime, data mortgages)

Safe, accurate deployment and recovery methodology:

- Precise siting and recovery in close proximity to MRE infrastructure
- Recovery methodology with small, low-cost, inspection class ROV