UNDERSTANDING THE RISKS OF TIDAL ENERGY DEVELOPMENT TO FISH USING ACOUSTIC TELEMETRY

Fundy Ocean Research Centre for Energy

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Outline

- Tidal power development & the Bay of Fundy
- Risk Assessment Program – context & objectives
- Species distribution modelling
- Next steps and applications beyond tidal energy

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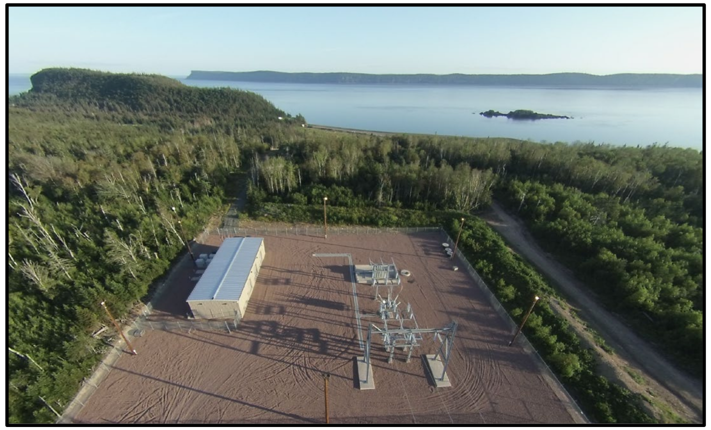
Fundy Ocean Research Center for Energy

- Canada's leading research center for demonstration and evaluation of tidal stream energy technology

- Fulfills mandate through two concurrent roles:
  I. Host - onshore/offshore infrastructure for project developers
  II. Steward - environmental monitoring, research and engagement



Bay of Fundy & Minas Passage

- World's highest tides – amplitude: 16m (56 ft)
- 14 billion tons of water each tidal cycle
- Strong current velocities (> 5 ms^{-1})
- Commercial potential : 2,500 MW per tide

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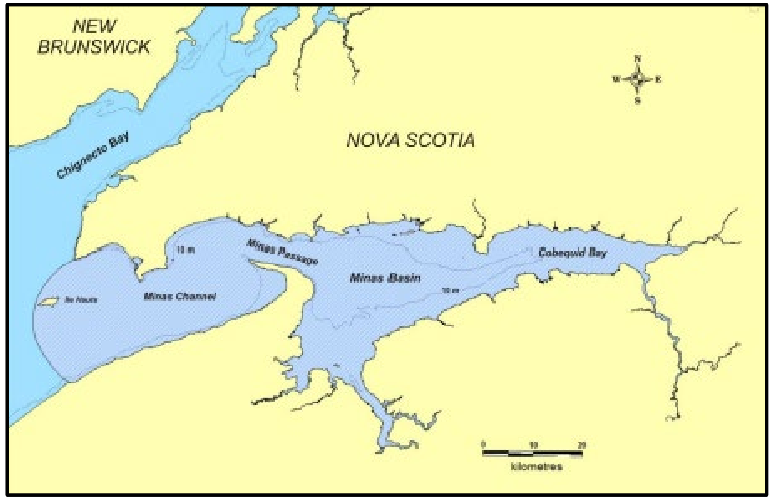
- Region identified as an 'Ecologically and Biologically Significant Area' (DFO 2018) – unique environment
- Important migratory corridor and habitat for 85 species of diadromous and marine fishes (Dadswell and Rulifson 2021)
    - species of conservation concern
    - cultural relevance to indigenous communities
    - commercial & recreational fisheries



OUTLINE

- TIDAL POWER DEVELOPMENT & THE BAY OF FUNDY
- RISK ASSESSMENT PROGRAM – CONTEXT & OBJECTIVES
- SPECIES DISTRIBUTION MODELLING & ENCOUNTER RATE MODELS
- NEXT STEPS AND APPLICATIONS BEYOND TIDAL ENERGY

Source: afloat.ie

RAP CONTEXT

- Environmental permitting is on the critical path to tidal device deployments
- Collision risk is perceived as the greatest threat from turbine operations
- Regulators have requested information about the risk of fish-turbine interactions in Minas Passage
- Collisions are difficult to observe directly
- We can quantify risks through the development of species distribution models (SDMs) and encounter rate models (ERMs)

RAP Objectives & Approach

- Develop statistically robust encounter rate models to quantify the risk of tidal stream energy development to fish species in Minas Passage, and thereby facilitating sector growth
  - use species distribution models to build predictive maps (today's presentation)
  - integrate turbine-specific parameters to quantify risk of encounter in space and time

frontiers

Modeling the Probability of Overlap Between Marine Fish Distributions and Marine Renewable Energy Infrastructure Using Acoustic Telemetry Data

Charles W. Bangley[1*], Daniel J. Hasselman[2], Joanna Mills Flemming[1], Frederick G. Whoriskey[3], Joel Culina[2], Rod Bradford[4]

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HYDRODYNAMICS ARE IMPORTANT

- Hydrodynamics influence fish spatiotemporal distributions in tidal channels

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ELSEVIER

Original Articles

Fine-scale hydrodynamic metrics underlying predator occupancy patterns in tidal stream environments

Lilian Lieber[a,*], W. Alex M. Nimmo-Smith[b], James J. Waggitt[c], Louise Kregting[a]

ARTICLE

https://doi.org/10.1038/s42003-019-0364-z OPEN

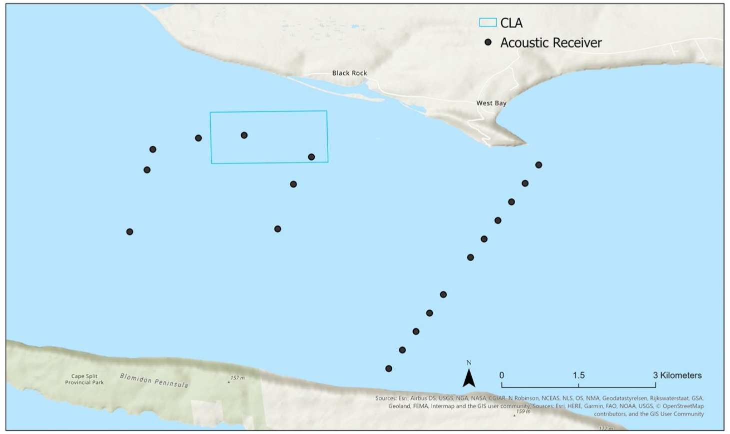
Localised anthropogenic wake generates a predictable foraging hotspot for top predators

Lilian Lieber[1], W. Alex M. Nimmo-Smith[2], James J. Waggitt[3] & Louise Kregting[1]

GENERAL APPROACH

- Build predictive models of the probability of species presence/absence based on the relationship between acoustic tag detections and environmental variables at acoustic receiver stations
  - permits ‘forecasting’ of species distributions in other locations based on environmental features

Tag detections in Minas Passage



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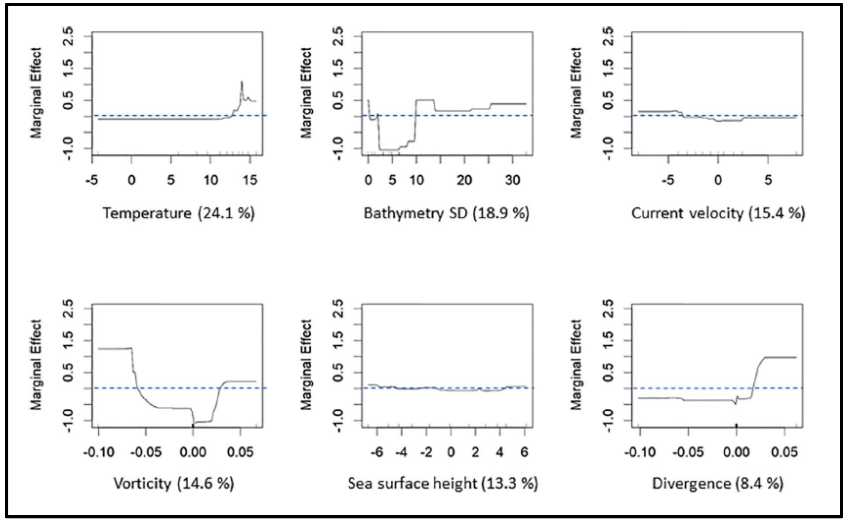

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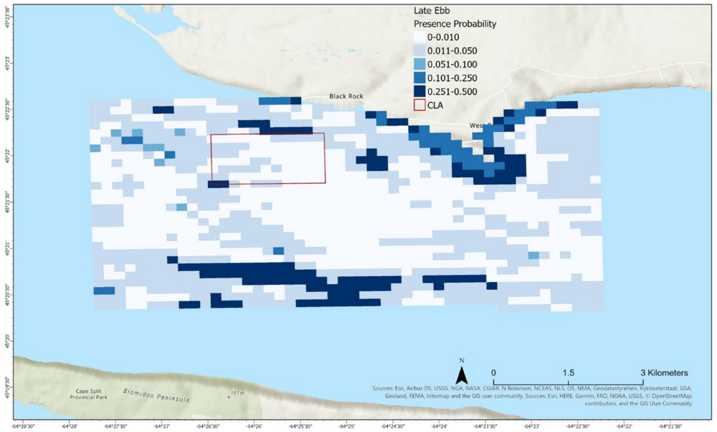
Species distribution



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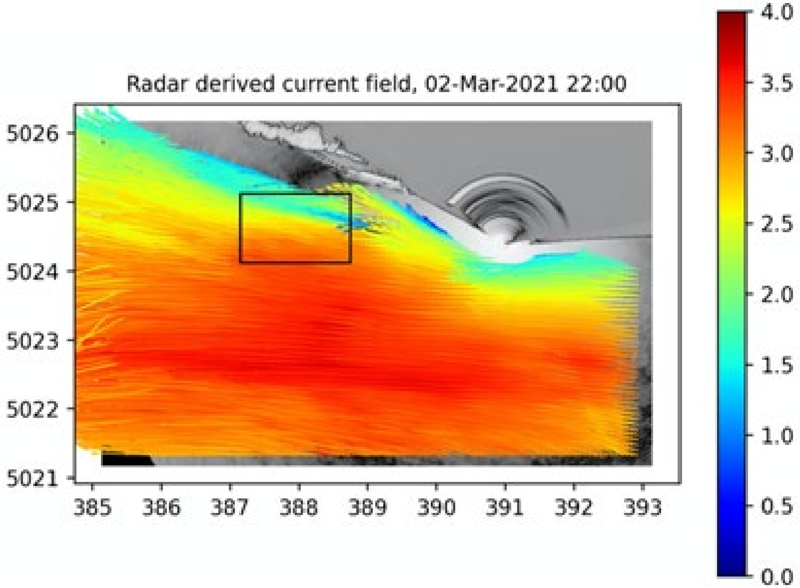
COMPLEMENTARY DATA

- Environmental data
  - surface X-band radar (current velocity, vorticity, sea surface height)
  - high-resolution bathymetry (depth and bottom complexity)
  - water temperature



COMPLEMENTARY DATA

- Environmental data
  - surface X-band radar (current velocity, vorticity, sea surface height)
  - high-resolution bathymetry (depth and bottom complexity)
  - water temperature

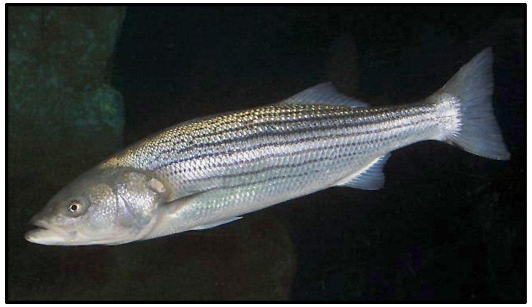
- Acoustic tag detections (numerous receiver stations)
  - species presence/absence
  - 9 species – data from 22 partners (17 projects)

Species Distribution Model (SDM)

- Boosted Regression Tree (BRT) analysis:
  - ideal for species distribution modelling because it is insensitive to most error distributions common to ecological data, deals well with multicollinearity of explanatory variables, and outliers (Elith et al. 2008; Dormann et al. 2003)
  - R package: gbm.auto (Dedman et al. 2017)

- Model details:
  - spatial resolution: 150 m^2
  - temporal resolution: 1-hour
  - results presented by tidal stage (i.e., slack high/low, early/mid/late flood & ebb)

- Demonstration:
  - striped bass model (Oct-Dec: 2017-2020)



Marginal Effects Plots

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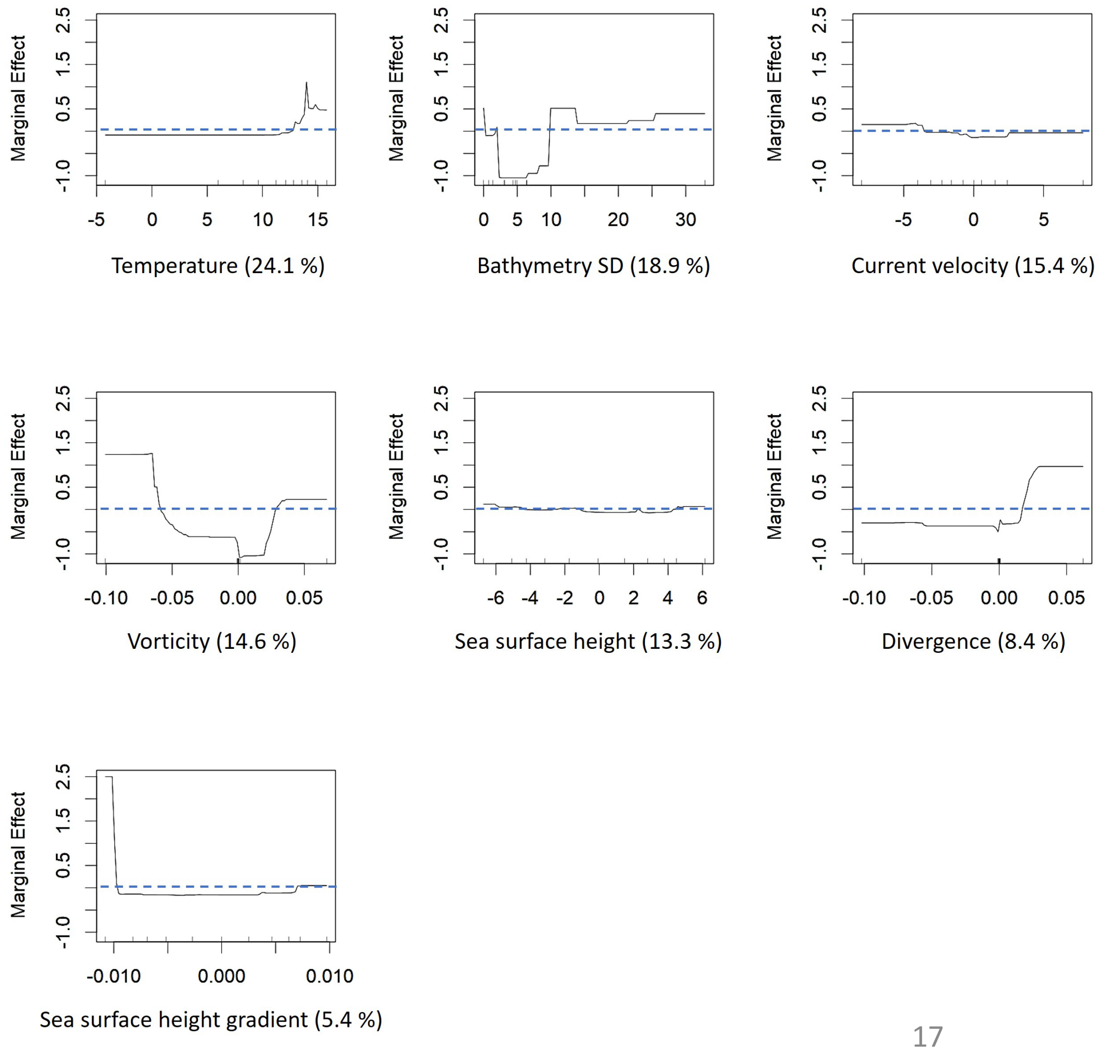
- Shows proportion of tree splits attributable to each explanatory variable
  - % = relative influence on the model
  - line > 0 = positive influence on species presence

- Striped bass presence in fall associated with:
  - water temperature >12.5 C
  - simple or very complex bottom types
  - high outgoing current speeds
  - turbulent hydrodynamics

- these relationships inform mapped estimates of presence probability
- relative importance and effects of variables can change between seasons



Striped bass SDM (fall 2017-2020)

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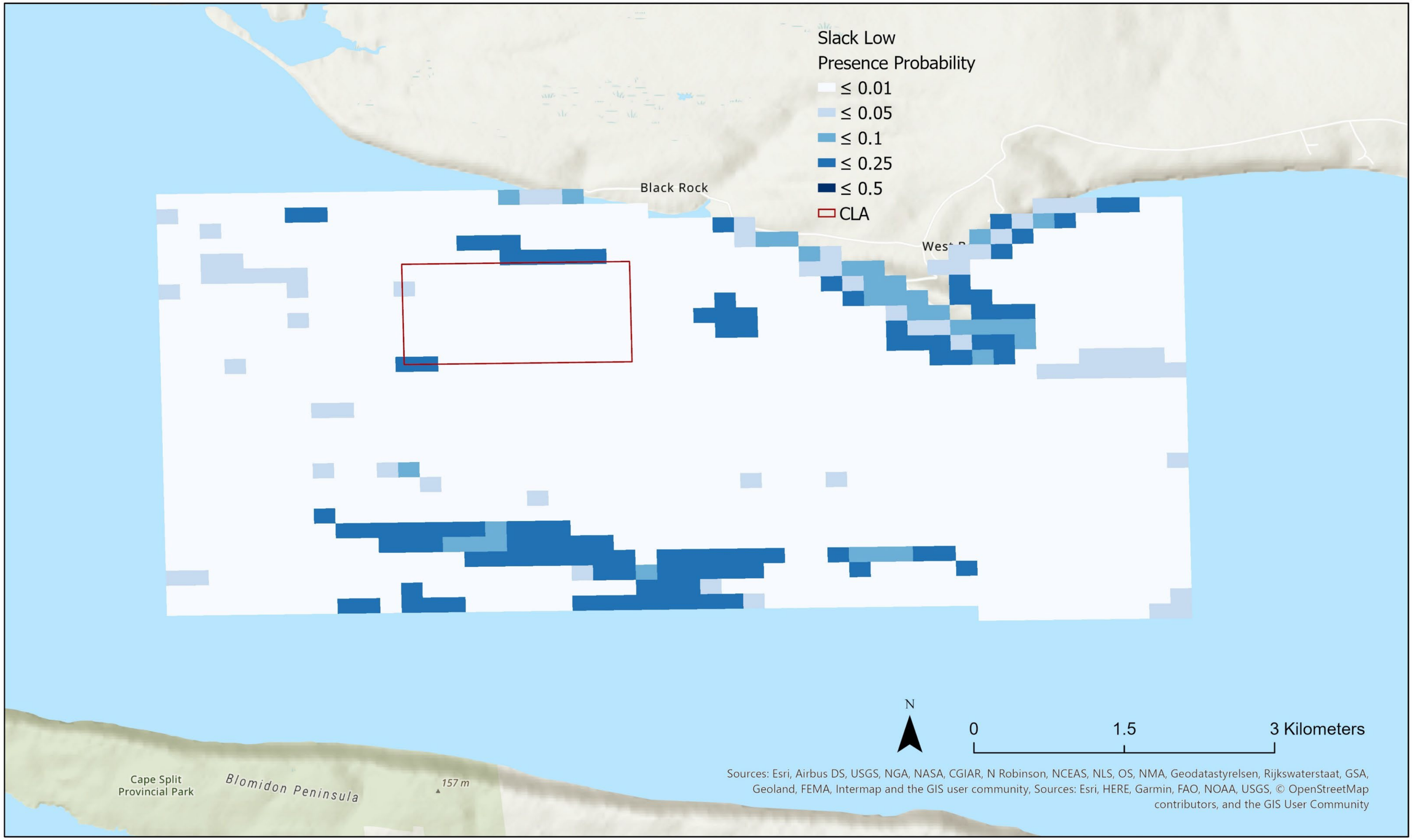

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Next steps: Encounter Rate Models (ERMs)

- First developed as a predator-prey model (Gerritsen and Strickler, 1977)
- Adapted to predict fish encounters with tidal stream turbines (Wilson et al. 2007)
- Encounter rate – the predicted rate of animals and turbines occupying the same point in space and time

- Site specific ERMs require:
  - spatial and temporal probability of fish presence (from SDM)
  - turbine characteristics (e.g., rotor diameter, # blades, rotation speed, etc.)

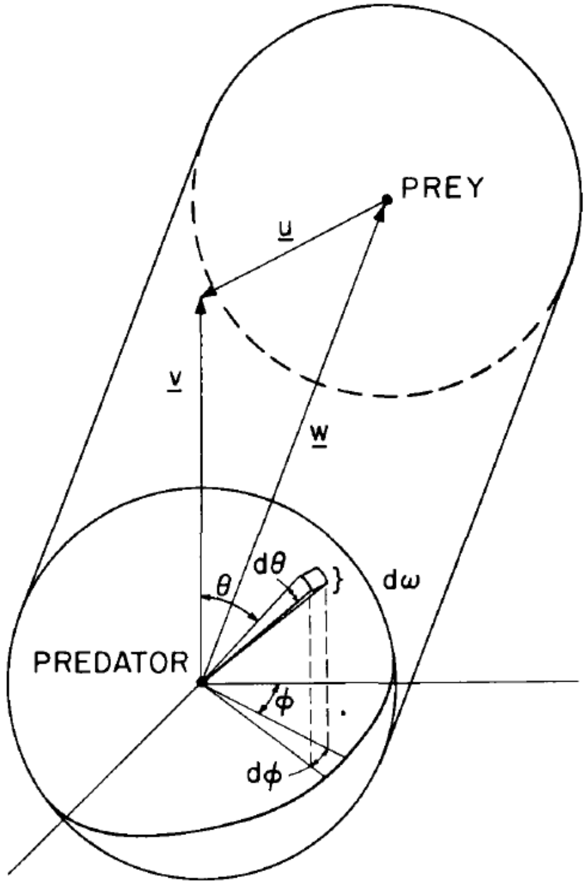


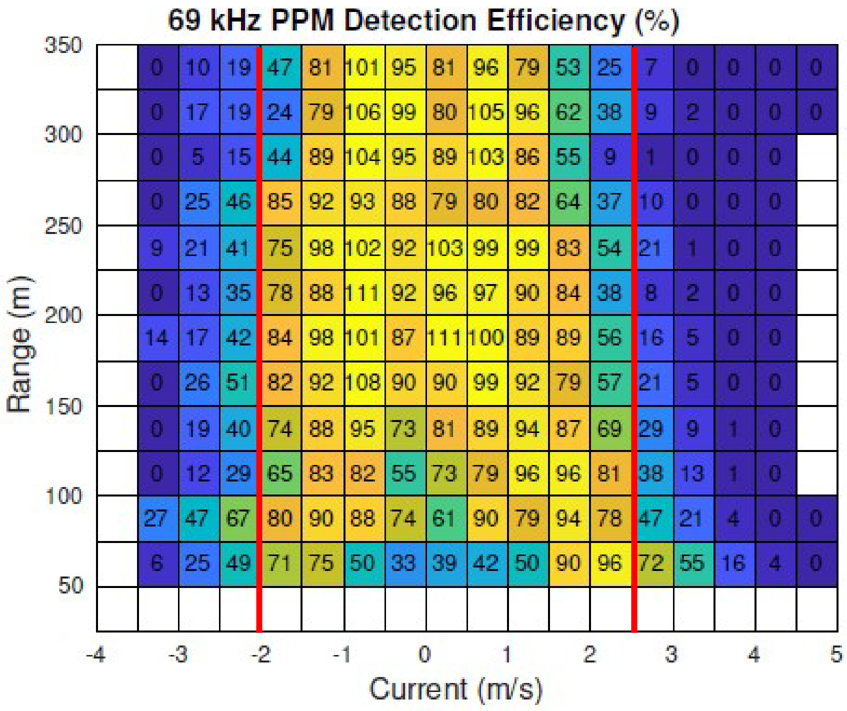
FIG. 1. The encounter sphere of a predator and the volume it sweeps as the predator searches for prey. See text for explanation.

NEXT STEPS: SDM EXPANSION AND REFINEMENT

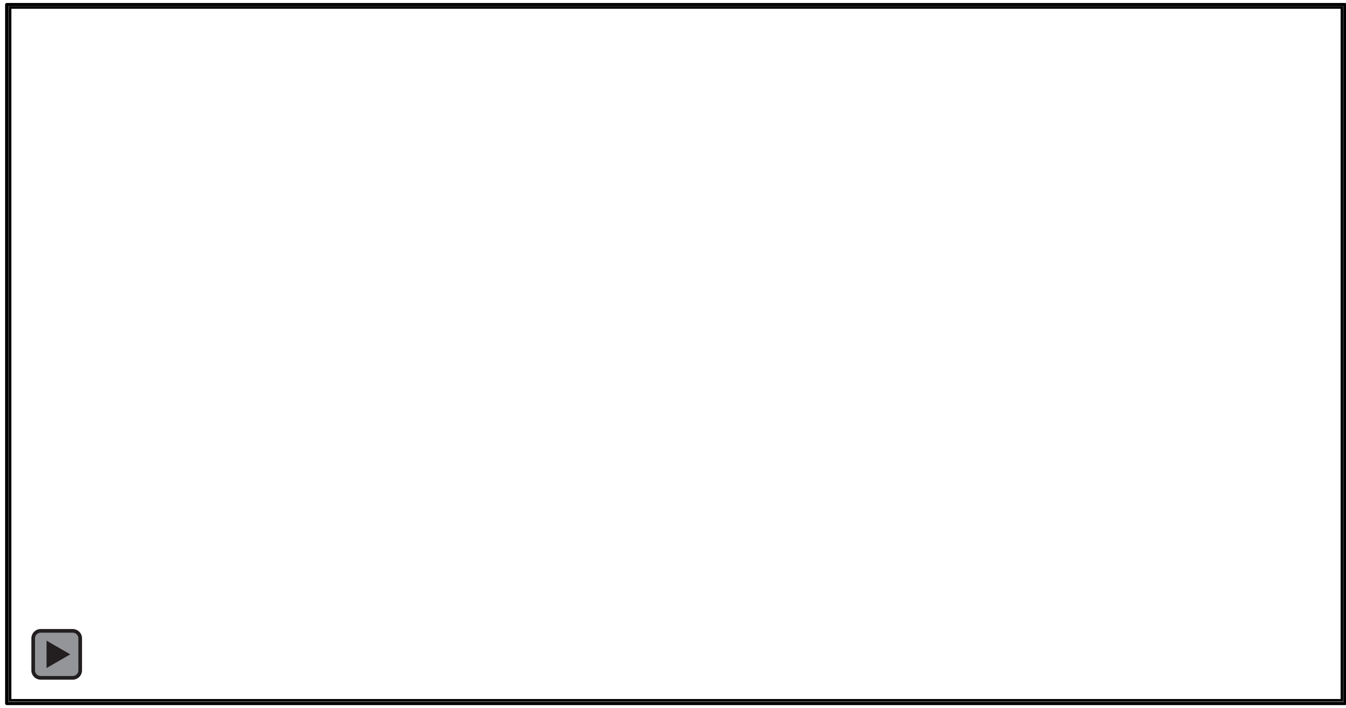
- Complete striped bass SDM for all seasons
- Expand SDM model framework to remaining eight species
- SDM validation:
  - acoustic tagging program underway
  - determine if tag detections confirm SDM predictions
  - integrate future detections to refine model predictions

Next Steps - Range Tests

- Incorporate acoustic receiver detection efficiency estimates from static and mobile range tests
  - required for calculating the # of fish per unit area estimated from tag detection data – integrated into SDM and ERM
- Tag detection reliable at low-moderate current speeds



Tag detection reliable



OTHER APPLICATIONS OF SDM APPROACH

- Marine spatial planning for other industries in Bay of Fundy & beyond
- Fisheries conservation and management
- Ecological applications

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QUESTIONS?