RISK ASSESSMENT PROGRAM FOR TIDAL STREAM ENERGY

Annual Report 2022

Overview

Tidal stream energy has the potential to become a significant contributor to clean energy targets and an important response to climate change. Canada is now witnessing a new wave of tidal energy activity in the Bay of Fundy, by companies such as Sustainable Marine, BigMoon Power, and Nova Innovation. But uncertainty around potential impacts on marine life has left the federal regulator, Fisheries and Oceans Canada (DFO), challenged to adequately assess the risk, particularly to fish. This uncertainty challenges the regulatory permitting process; without regulatory approval, developers cannot execute the planned project scope nor raise additional private sector funding to move forward.

Many perceive the greatest potential risk of tidal turbine operations as collisions between marine animals and turbines blades. These types of interactions are difficult to observe directly: both because of the fast flowing, turbid waters of tidal energy sites and because of the limitations of monitoring instruments which have been designed for use in more benign marine environments.

The Risk Assessment Program (RAP) for tidal stream energy is designed to create a detailed, credible assessment tool to gauge the probability that fish will encounter a tidal device. RAP is a collaborative effort between the Fundy Ocean Research Centre for Energy (FORCE), Ocean Tracking Network at Dalhousie University, the Mi'kmaw Conservation Group, Acadia University, and Marine Renewables Canada

A key deliverable of RAP is an encounter rate model (ERM): a mathematical model that estimates the frequency with which a stationary entity encounters a moving one — in this case, the probability that a fish will occuy the same volume of water as tidal stream turbine, thereby encountering the device (assuming no avoidance behavior by the fish). ERMs have become a standardized permitting tool for assessing the risk of offshore wind projects; until now, little work has been done to apply the concept to tidal turbine projects. The development of an ERM tailored specifically to tidal devices in the Bay of Fundy's Minas Passage will be game changing.

The probability of fish-turbine encounters will be determined by combining two complementary data sets: physical oceanographic (hydrodynamics), and biological (fish distribution). A radar-based **flow atlas** is the key input for determining water movement and direction; acoustic **fish-tagging** provides the data of central interest on different fish species and their location. With

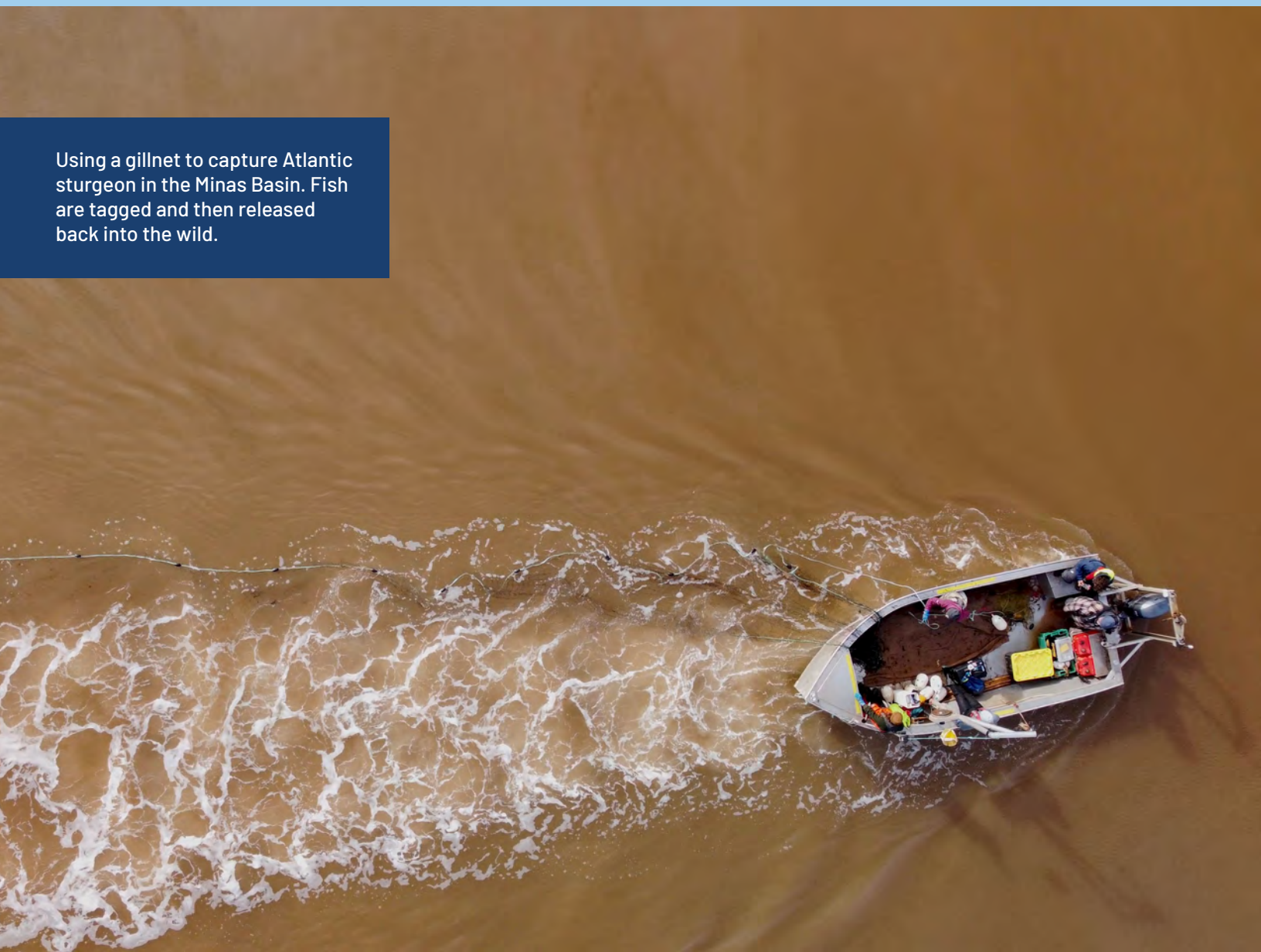
Overview continued...

unprecedented reach and accuracy, RAP combines data on water flow with fish location to understand fish movement in the Minas Passage, in real time.

RAP partners will be able to estimate, for the first time, the probability that a fish will encounter a turbine at specific locations in Minas Passage. That will give regulators, Rights Holders, fishers, developers and other stakeholders a clearer understanding of the potential risks to fishes of commercial, cultural, and conservation value in the Bay of Fundy in advance of tidal turbine deployments.

The inclusive design of RAP, which brings together many participants with diverse interests and concerns around the Fundy ecoystem, is also establishing the foundation for future environmental effects monitoring programs and best practices.

The RAP project is entering its third and final year. This report provides an update of the key program components: 1) flow atlas; 2) fish atlas; and 3) modelling.



Using a gillnet to capture Atlantic sturgeon in the Minas Basin. Fish are tagged and then released back into the wild.

FORCE, Acadia University

Flow Atlas

Breakthrough, radar-based data collection is delivering real-time hydrographic mapping of turbulence, eddies, and waves — all important influences on fish distribution.

RAP has established a high-resolution radar network in the Minas Passage, which is now generating spatiotemporal (space and time) data on physical oceanographic features. This is the basis for real-time mapping and flow atlas development for the Minas Passage.

Installing a high-resolution marine radar at the FORCE facility, overlooking the Minas Passage.

Flow Atlas continued...

These new marine radars reflect off the sea surface with high resolution in space and time, providing a birds-eye view of the moving wave field, from which wave statistics, current velocity, and eddy structures can be derived; all these hydrodynamic features can affect the spatiotemporal distributions of fish.

The first data set, composed of physical oceanographic data, is being generated using a high-resolution radar network, combined with stationary acoustic Doppler current profiler (ADCP) and hydrodynamic model data, to create the first spatiotemporal flow atlas for Minas Passage.

The radar is measuring, in high resolution, unique features in the flow-field that are affecting fish distribution, including:

- During the ebbing tide phase, the tidal flow separates off Cape Sharp and produces huge eddies that move through Minas Passage as the flow rate increases.
- On the ebbing tide phase, a giant wake appears behind Black Rock.

Radar imaging reveals spiralling eddies, in real time, that can significantly impact the distribution of fish. See time-lapse video of radar data in the Minas Passage: fundyforcelive.ca/#!/radar

Flow Atlas continued...

Key Outcomes to Date

- *Radar network installation: Installed two radars providing full coverage of Minas Passage.*
- *Assembly and commissioning of a third mobile radar system for further Fundy coverage.*
- *Radar validation: Against numerical model and ADCP data.*
- *Established and derived flow and physical variables: sea surface height (SSH), SSH gradient, velocity, velocity gradient, depth, depth variance, water temperature.*
- *Matched radar-derived flow and historical fish data towards establishing their functional relationship.*

New high-resolution marine radar installed at Cape Sharp, Minas Passage.

Next Steps

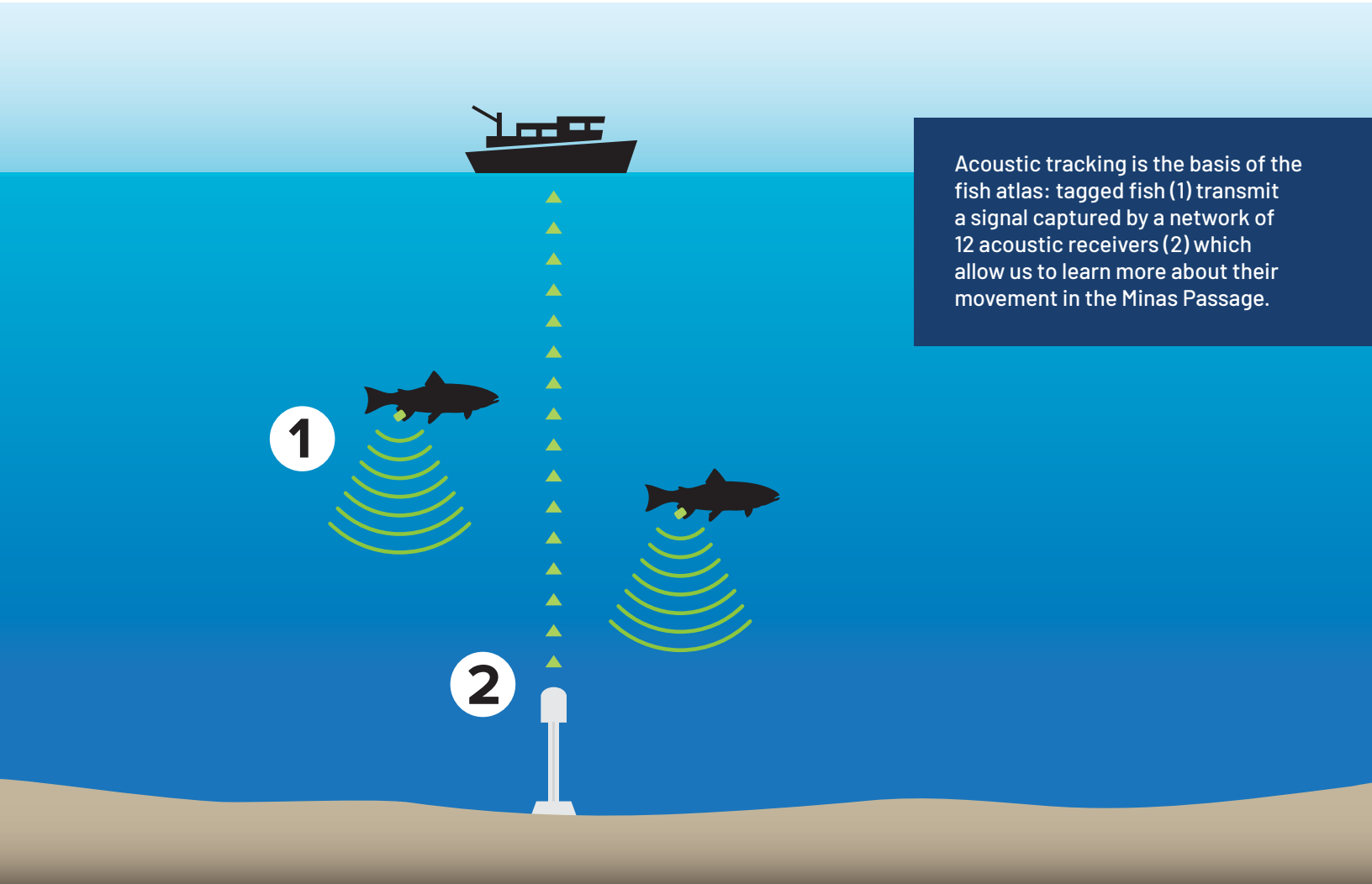
- Conduct ADCP hydrographic surveys of currents, eddies, and waves through the water column to validate the radar data.
- Develop full suite of software for mapping and real-time monitoring of tidal stream currents and wakes. This builds on existing National Oceanography Centre software, adapted to tidal streams.
- Complete Flow Atlas development for the Minas Passage.

Dalhousie University, Ocean Tracking Network (OTN), Mi'kmaw Conservation Group (MCG), Acadia University, fishing community members

Fish Atlas

Thanks to the collaboration of many partners, RAP is building the largest spatiotemporal, multi-species fish map in the Bay of Fundy ever created.

The fish atlas is an unprecedented collaborative effort to collect, combine and analyze mutltiple data sets of hydroacoustic fish-tagging studies — both existing and new. The studies cover nine (9) species: alewife, American shad, American eel, Atlantic salmon, Atlantic sturgeon, Atlantic tomcod, spiny dogfish, striped bass, and white shark.



Acoustic tracking is the basis of the fish atlas: tagged fish (1) transmit a signal captured by a network of 12 acoustic receivers (2) which allow us to learn more about their movement in the Minas Passage.

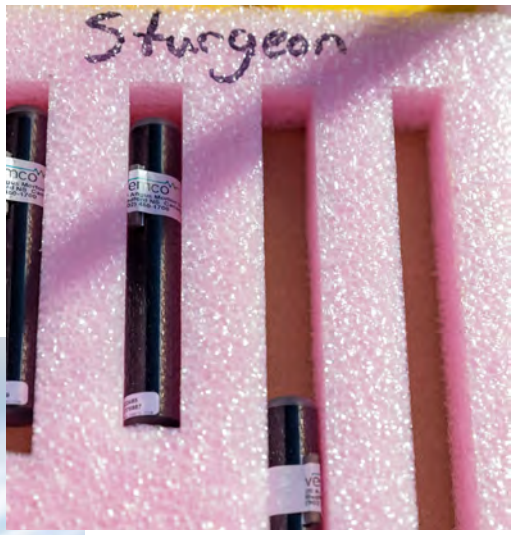
Fish Atlas continued...

The species were chosen based on historic tagging data availability, conservation concern and value to commercial, recreation, and Mi'kmaq fisheries, and current coverage through prior and ongoing acoustic tracking studies.

Over the last decade, hydroacoustic receivers deployed throughout the Bay of Fundy have collected movement data from a variety of fish carrying acoustic tags. These data originate from a series of separate research programs in Canada and the United States, and provide an enormous resource for understanding the spatiotemporal distributions for a number of fish species in the Bay of Fundy.

Tracking data from each species is being combined with flow atlas data to create nine species distribution models (SDMs). An SDM is essentially a "forecast" map for the presence of individual fish species; together, the nine SDMs comprise the biological atlas or "fish atlas."

Mi'kmaw Conservation Group (MCG) has led a new fish-tagging program to validate predictions about spatiotemporal species distributions based on the first iteration of the SDMs. This data will help determine whether these new tag detections fall within the model-predicted areas of fish presence. For the 2021 program, a total of 96 fish for four target species were captured and had acoustic tags surgically implanted. The tags emit "pings," heard by acoustic receivers deployed in the Minas Passage. The data from other fish tagging programs, in addition to stakeholder input, will additionally be utilized to validate the models.



Above: Acoustic tags come in different formats and can last up to a decade. Most RAP tags are commonly used frequencies of either 69 kHz or 180 kHz. The choice is mostly dependent on fish size (smaller fish get smaller tags), receiver type and placement.

Below: A tag is an acoustic transmitter, surgically implanted in a fish. Each tag emits a unique sound pattern that underwater tracking stations (receivers) can detect. Tags allows us to learn more about a fish's history, distribution, biology, ecology, mating, travel, and more.

Fish Atlas continued...

Key Outcomes to Date

- *Compiled a huge acoustic tag detection data set through data agreements facilitated by OTN from 22 data holders for nine species.*
- *All data sets accessed through OTN analyzed; development of the species distribution models (SDMs) is nearing completion and the model framework has been published in a peer-reviewed journal (please see below).*
- *A preliminary test deployment of the receivers was conducted to validate the hearing range of the receivers and to determine where the receivers should be placed for the validation study.*
- *Deployment of 12 receivers within Minas Passage.*
- *Coordinated with FORCE physical oceanography team to acquire environmental data to combine with acoustic tag data to build SDMs.*
- *Demonstration SDM using striped bass tag detections and environmental data from Oct–Dec 2017–2020.*
- *Commitment by Sustainble Marine to purchase a portion of 2022 acoustic fish tags.*
- *Commencement of fish tagging program using different collection methods:*
  - *alewife (captured using dipnets): Avon and Gaspereau Rivers*
  - *American shad (captured using beach seines): Kennetcook River*
  - *Atlantic salmon (captured in collaboration with Fisheries and Oceans Canada): Gaspereau River*
  - *Atlantic sturgeon (captured using a gillnet): Minas Basin*
  - *Spiny dogfish (captured using baited longline): Minas Basin.*
- *Meetings with regulators about the modeling approach reaffirmed that the RAP program is generating important and relevant information to assess the risk of tidal stream project development to fish in Minas Passage.*
- *A peer-reviewed research paper outlining the RAP program and species distribution modelling approach has been accepted for publication in "Frontiers in Marine Science."*

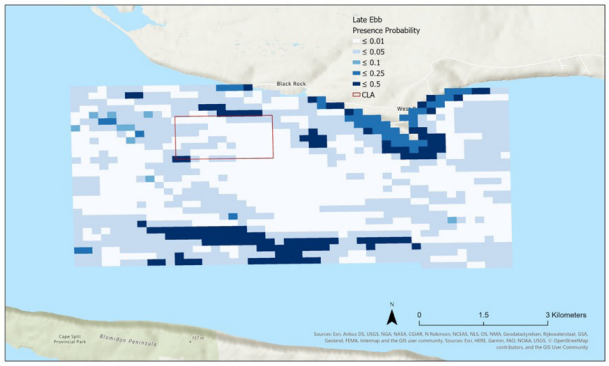
Next Steps

- Finish developing fish distribution models for all nine (9) species: complete the Fish Atlas.
- Work with OTN to merge the RAP line of acoustic receivers with the Minas Passage line to establish a continuous line of acoustic receivers across the entire Minas Passage to improve fish tag detections.

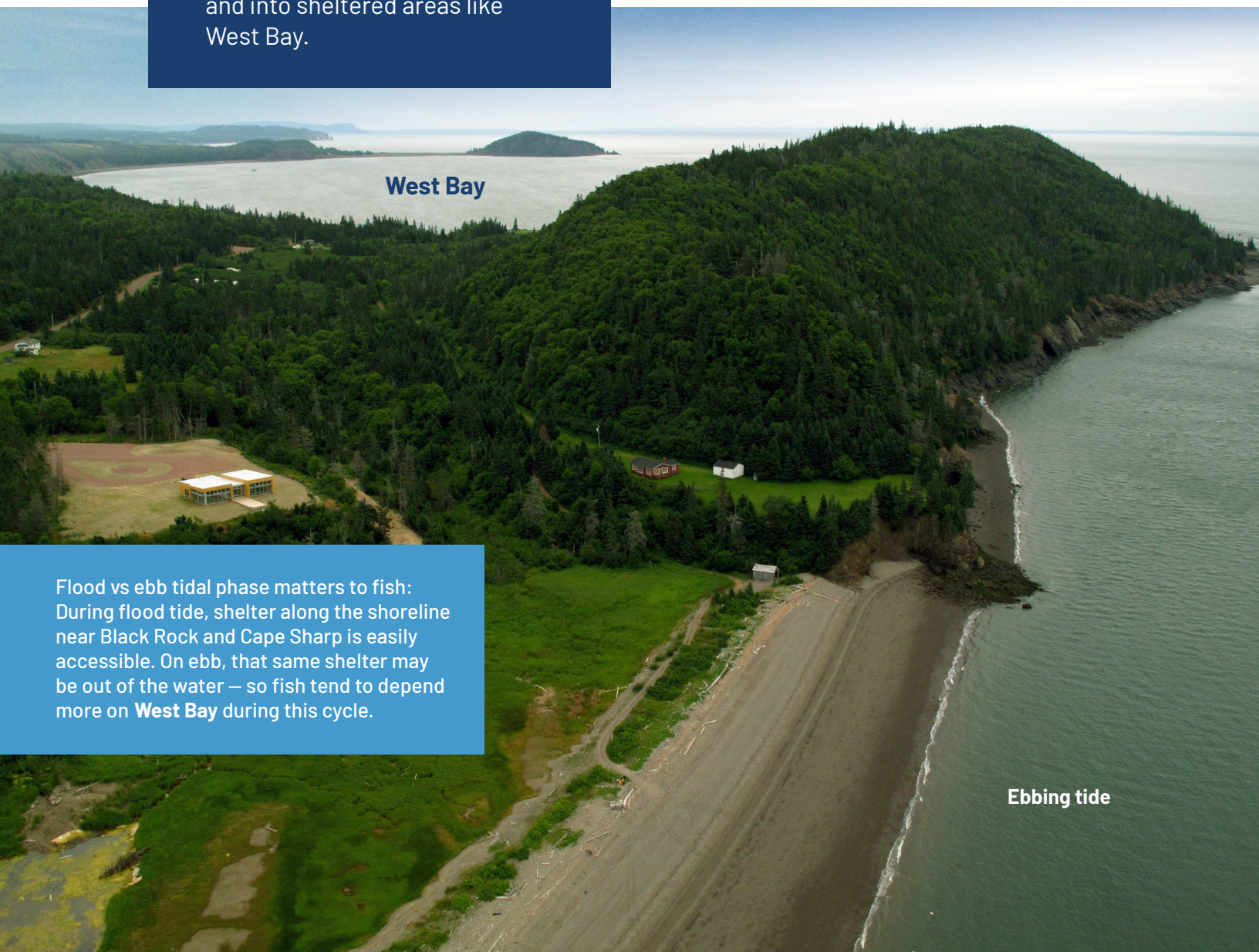
Fish Atlas continued...

Observations

- Fish movements in Minas Passage are strongly influenced by tidal currents.
- At slower-current tide stages, fish in the passage are able to spread out in the relatively slow, calm water.
- As current speeds pick up, fish tend to move closer to shore and into sheltered areas like West Bay.



Above: Tracking data reveals significant presence of striped bass along the FORCE beach, Cape Sharp, and into West Bay during the later stage of an ebb tide.



Flood vs ebb tidal phase matters to fish: During flood tide, shelter along the shoreline near Black Rock and Cape Sharp is easily accessible. On ebb, that same shelter may be out of the water — so fish tend to depend more on **West Bay** during this cycle.

Fish Atlas continued...

Analysis

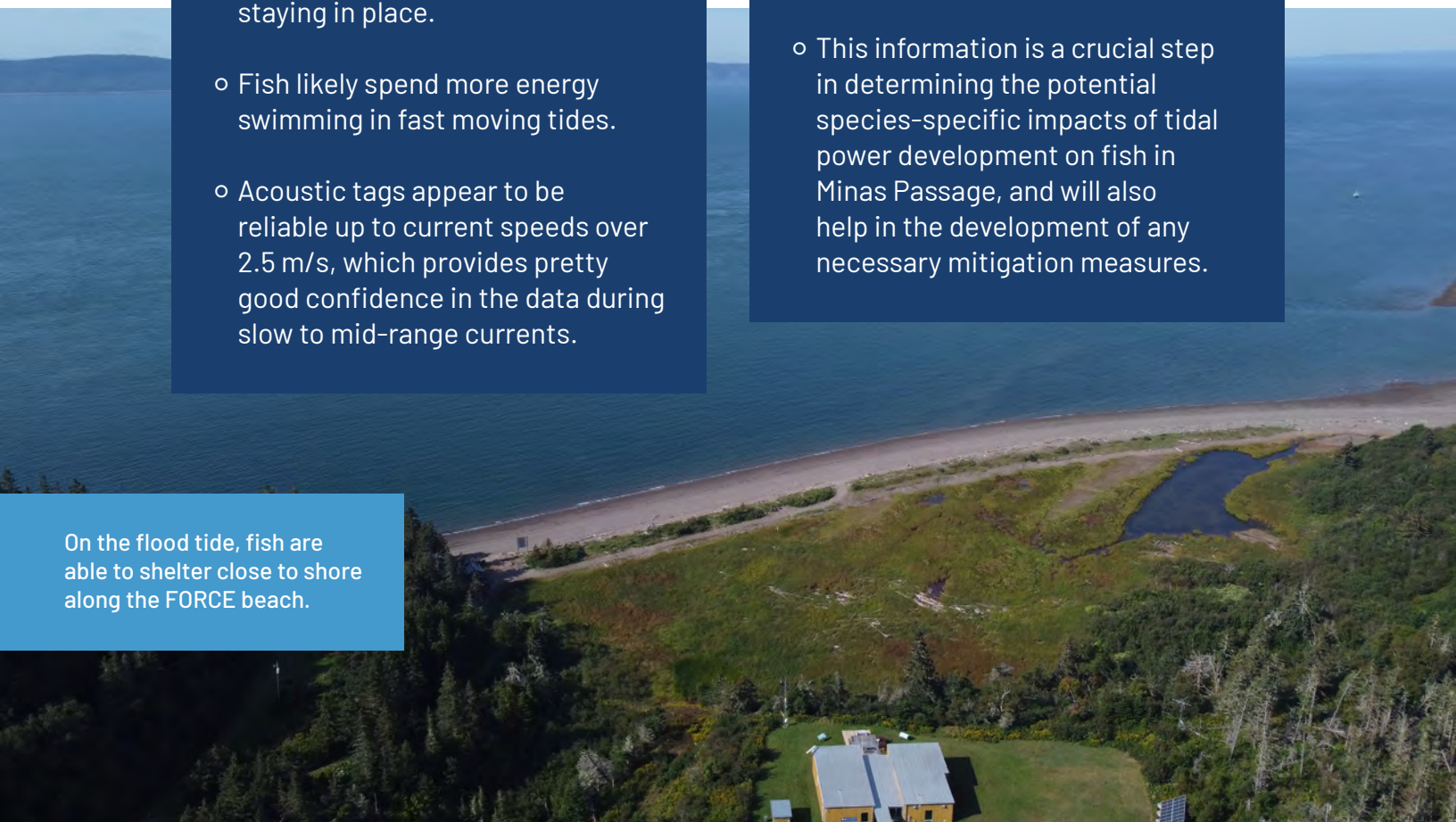
SLOWER CURRENTS = MORE FISH DETECTIONS

- Low current speeds allow them to move freely and forage within the passage: at slack tide, more fish are present in the open parts of the passage.
- As current speeds increase, fish move out of the passage: on the flood, generally eastward; on the ebb, generally westward, or moving towards the shoreline and into sheltered areas.
- In sheltered areas, fish are less exposed to fast currents and have to expend less energy just staying in place.
- Fish likely spend more energy swimming in fast moving tides.
- Acoustic tags appear to be reliable up to current speeds over 2.5 m/s, which provides pretty good confidence in the data during slow to mid-range currents.

Interpretation

The preliminary results suggest:

- The most likely **time** of potential overlap between fish and tidal device locations is during low current speeds, but this will vary by species.
- The risk of harm to fish at lower current speeds is likely lower as turbine blades are moving slower.
- The most common **route** for fish movement through the Minas Passage is generally either towards the middle, along a 160-metre deep canyon, or very close to the shoreline, but this also varies by species.
- This information is a crucial step in determining the potential species-specific impacts of tidal power development on fish in Minas Passage, and will also help in the development of any necessary mitigation measures.



On the flood tide, fish are able to shelter close to shore along the FORCE beach.

Dalhousie University, Ocean Tracking Network, Mi'kmaw Conservation Group, Acadia University, fishing community members

Encounter Rate Models Development

Each species distribution model (SDM) will form the basis of a corresponding encounter rate model (ERM) — one for each species — which considers tidal device features and locations.

Species distribution models will be translated into encounter rate models (ERMs) by taking into consideration various aspect of tidal turbine design (e.g., floating vs. bottom-mounted, swept area, revolutions per minute) and incorporating that information into the model structure.

Acoustic receivers (69 kHz and 180 kHz) mounted on yellow mooring buoys for deployment in Minas Passage. See a video of the deployment: vimeo.com/552989257

Encounter Rate Models Development continued...

This will provide a probabilistic approach for determining the risk of differing turbines to various species in Minas Passage, and is an important component for assessing risk of tidal turbine development.

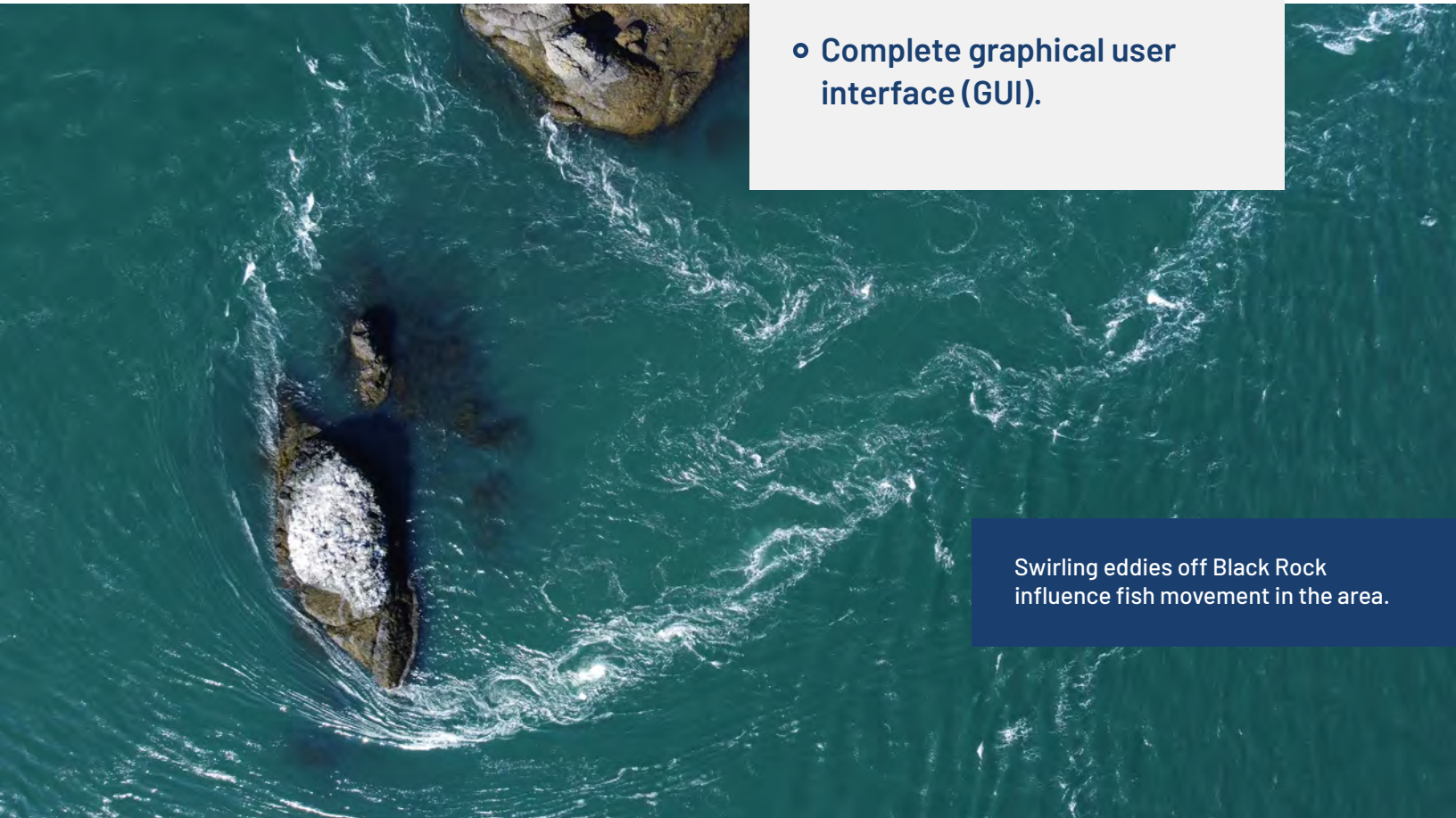
The final output will be an accessible graphical user interface that will be developed where stakeholders can adjust inputs for variables of interest (species, time of year, various turbine characteristics) to develop species-specific risk profiles.

Key Outcomes to Date

- *Compiled turbine-specific pararmeters for various tidal turbine designs.*

Next Steps

- **Commence development of encounter rate model for striped bass as a template for the remaining species.**
- **Integrate turbine-specific parameters into model framework to transition SDM to ERM.**
- **Complete fish tagging program.**
- **Validate ERMs with next deployed turbine; recover receivers quarterly and use data, and data from other projects.**
- **Complete graphical user interface (GUI).**



Swirling eddies off Black Rock influence fish movement in the area.

Mi'kmaw Conservation Group, Marine Renewables Canada (MRC), Ocean Tracking Network, FORCE

Engagement

The success and credibility of the risk assessment program depends on partnership, representation, and inclusion of the many groups with an interest in tidal development activity, including regulators, industry, Rights Holders, fishers, community members, the academic community and more.

Engagement for the RAP project serves not only to inform, but to provide input into the study design, the data collection, and the outputs.

Hauling a gillnet onboard.

Engagement continued...

Engagement with project partners has been ongoing since the start of the project. Reaching out to the fish tagging data set owners and having them not only agree to share their data but also join as project partners speaks to the groundbreaking and worthwhile goals of the project.

We have been holding regular meetings with regulators; Mi'kmaw Conservation Group, Ocean Tracking Network and FORCE have coordinated engagement efforts with Bay of Fundy mainland Mi'kmaq communities. Goals of this work includes increased participation in fish tagging, gathering visual material and learning, combining traditional and scientific knowledge to understand how principles of Netukulimk (appropriate resource use) and Etuaptmumk (two-eyed seeing) align with the biological atlas, reaching out to community members for information sharing to support the graphic user interface.

Key Outcomes to Date

- *All 22 data holders with their spatiotemporal data sets curated by OTN agreed to share their data with and be partners on this groundbreaking project.*
- *An advisory group of local experts in acoustic telemetry was created and engaged to provide input and advice on developing the Fish Atlas and ERMs, consisting of academic, regulatory, and Mi'kmaw members.*
- *Completion of Mi'kmaw Ethics Watch application.*
- *Rightsholder/stakeholder interviews for GUI design.*
- *Scoping and design of user interface.*
- *Industry engagement meetings.*
- *Presentation at Fisheries Conference for Atlantic Policy Congress of First Nations Chiefs.*
- *Virtual open house for Mi'kmaw community engagement.*

Next Steps

- **Continue to collaborate with all project partners and regulators.**
- **Fish tagging, training, and traditional knowledge sharing.**
- **Additional outreach to Mi'kmaw community to share stories and traditional knowledge to incorporate Two-Eyed Seeing (Etuaptmumk) approach into RAP.**
- **GUI build, testing, completion.**

Summary

RAP can enable marine renewable energy to form part of Canada's expanding portfolio of clean energy sources and thereby meet its commitment to reducing greenhouse gas emissions.

RAP is a critical addition to work currently underway to monitor and assess environmental impacts related to tidal stream energy development.

Working in partnership with key organizations involved in the Bay of Fundy ecosystem is fundamental to the program's ongoing success. Together, partners are building the largest data set of fish distribution and movement patterns in the Bay of Fundy, combining scientific, local and traditional knowledge in study design, participation, and output to better understand the risk of fish encountering a turbine. The fish tagging and species distribution modelling work is providing novel insights into how the Bay of Fundy ecosystem functions, including information about migratory behaviour and timing, species interactions, and areas of occupancy for species of conservation concern. This knowledge will be shared by developing a graphical user interface to make this data available to everyone with an interest in the continued health of the Fundy watershed.

The integration and accessibility of this data set is unprecedented, and can serve as an important tool for considering the potential impacts of any activity in the Bay of Fundy on the marine ecosystem. The project also provides a novel platform for scientific, Mi'kmaw, fishing and other communities to observe the movement and distribution of multiple fish species in the region, supporting important collaborations in multiple ocean sectors.

The Government of Canada has invested $90 million in MRE technology research and development in the Bay of Fundy, intended to help meet clean energy and climate change goals. This investment must be protected by the biological information and tools needed to accurately assess potential risks of this emerging clean energy sector to marine life, particularly fish species of conservation concern. The RAP program will help inform marine planning and policy, regulation, monitoring, mitigation, offsets and/or other strategies to ensure that MRE development can proceed responsibly, and include the participation of industy, scientific, Indigenous, fishing, and other connected communities.

Through its support of RAP, the Government of Canada has made a critical, strategic investment in protecting a Canadian industry with the potential to contribute up to $1.7 billion in gross domestic product (GDP), create up to 22,000 full time positions and generate as much as $815 million in labour income by 2040.[1]

[1] "Value Proposition for Tidal Energy Development in Nova Scotia, Atlantic Canada and Canada" (commissioned by the Offshore Energy Research Association (OERA) of Nova Scotia)

Summary continued...

Key Project Benefits:

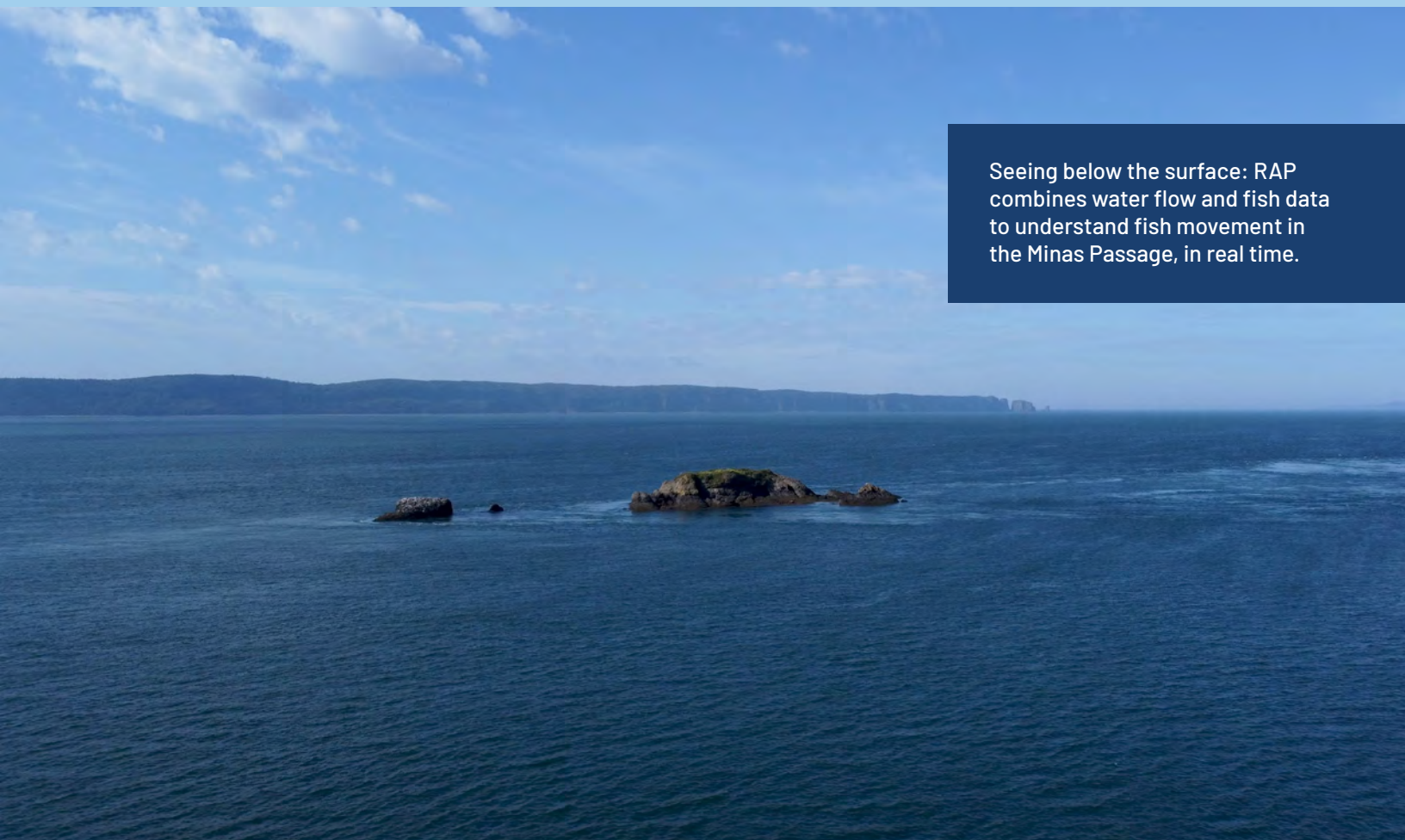
A Tool for Regulators
To quantify risk and inform parameters around authorization and potential conditions.

An Ecosystem-wide Approach
Making information from multiple projects accessible, and facilitating the collection of species-level information, for assessing potential impacts.

Species-specific Risk Assessment
To support evidence-based discussion around the concept of Netukulimk for Mi'kmaq, Wəlastəkwewiyik and Passamaquoddy communities.

Improving Accuracy
Ongoing fish data collection will serve to update and validate risk metrics, and to improve the integrity of the model with longer term data sets.

A Single User Interface
Responsive to key variables such as type of turbine, location, and species of fish.



Seeing below the surface: RAP combines water flow and fish data to understand fish movement in the Minas Passage, in real time.

Key Project Partners

Acadia University
A leading academic institution conducting research in the Bay of Fundy as well as tidal energy research, training, education and outreach to promote responsible approaches to tidal energy development.

Fundy Ocean Research Centre for Energy (FORCE)
FORCE is Canada's leading research facility for tidal stream energy technology. FORCE provides offshore and onshore electrical equipment to connect devices to the power grid, and conducts monitoring and research to understand any potential environmental effects.

Marine Renewables Canada (MRC)
MRC is Canada's lead wave, tidal, river and offshore wind energy association, representing local and international developers, utilities, researchers, and suppliers. Since 2004, MRC has supported the development of the marine renewable energy industry with collaborative opportunities, information and outreach.

Mi'kmaw Conservation Group (MCG), Confederacy of Mainland Mi'kmaq
MCG's mandate is to restore the concept and practice of Netukulimk in the region's watersheds; Netukulimk is based on showing respect to the lands by taking only what is needed and wasting nothing. MCG endeavours to respond to watershed challenges such as commercial use, population growth, pollution and global warming.

Ocean Tracking Network (OTN), Dalhousie University
OTN is a global aquatic animal tracking, technology, data management and partnership platform. OTN and its partners are using electronic tags to track more than 240 keystone, commercially important, and endangered species worldwide.

THANK YOU TO NATURAL RESOURCES CANADA FOR ITS GENEROUS SUPPORT.