OCEAN TRACKING NETWORK

2022 ANNUAL REPORT

Contents

Reef sharks. Philip Hamilton/Ocean Image Bank

Message from the directors

Since 2008, the Ocean Tracking Network (OTN) has been creating a research, data management and infrastructure platform that tightly integrates biological, oceanographic and social sciences, promotes technological innovation and fosters collaborative partnerships across sectors and around the world.

As we look back on the past year, we can also excitedly look forward to the next six. In August of 2022, OTN was awarded a grant of $38.5 million from the Canada Foundation for Innovation's (CFI) Major Science Initiatives Fund, bringing the total amount awarded to OTN for its 2017-2029 funding cycle to $65.6 million.

This continued investment will allow OTN to maintain and advance its operations and activities, while remaining agile and adaptable to emerging science priorities in Canada and internationally.

Since its last funding award from CFI, the reach and impact of OTN has grown exponentially. The Network has more than doubled its registered users and networked investigators. Detection data from network collaborators has increased four-fold, from 250 million to more than one billion records, and OTN's marine gliders have travelled over 138,936 kilometers—more than three times the Earth's circumference!

Over the next six years, the funding will allow OTN to expand the core operations and activities that underpin the Network's mandate. In particular, the funding will enable OTN to continue to advance new and innovative ways of tracking aquatic species, including delivering on its world-class marine glider program, expanding subsea robotics activities and supporting the integration of satellite-derived animal movement data into the OTN Data Centre.

OTN will also continue to help Canada meet its commitments to the United Nations (UN) Decade of Ocean Science for Sustainable Development (2021-2030). On World Oceans Day 2022, the United Nations Educational, Scientific and Cultural Organization (UNESCO) endorsed nine projects as part of this Ocean Decade. Six of those projects, including OTN, are nestled under the Marine Life 2030 program. As part of this commitment, OTN is addressing three specific challenges identified by UNESCO: protecting and restoring ecosystems and biodiversity; expanding the global ocean observing system for the delivery of actionable data and information; and improving equitable access to data and information across all aspects of ocean science. OTN's contributions to the Ocean Decade will help advance the UN Sustainable Development Goals that have formed the basis for Dalhousie University's signature research clusters.

Fred Whoriskey and Sara Iverson

At headquarters, OTN has scaled up on-campus operations with cautious optimism that COVID-19 restrictions will remain eased. Most staff members are working to a hybrid schedule—striking a balance between safe distancing while creating space for the side-of-desk coffee chats that often lead to new ideas and solutions and are an intrinsic element of OTN's collaborative culture.

Finally, we welcome Robert Lennox of the Norwegian Institute for Nature Research as OTN's incoming scientific director and tenure-track associate professor in Dalhousie's biology department. Over the years, Rob has been extraordinarily dedicated to OTN and generous with his time in helping other researchers and collaborators. He's committed to—and effective in—building partnerships, including through his position as co-chair of 'ideasOTN'—a committee of Canadian OTN students and postdoctoral fellows that formed to improve the synthesis of collaborative research outputs, help inform policy and management, and educate the public on ocean sciences. These characteristics of collaboration are at the heart of OTN, and Rob will without a doubt be a great mentor to students as a faculty member, a respectful and respected peer and leader, and an enthusiastic ambassador for the Network. Over the next year, Rob will work closely with the two of us as we transition the leadership of OTN into his capable hands. After 15 years at the helm, we look forward to moving into advisory roles to support Rob and the entire team as OTN continues to evolve.

We hope this review of our 2022 updates finds our readers well, and we look forward to the next phase of OTN as staff and collaborators continue to drive aquatic telemetry forward in Canada and across the globe.

FRED WHORISKEY, Executive Director

SARA IVERSON, Scientific Director

About OTN

The Ocean Tracking Network (OTN) is an aquatic research, data management and partnership platform headquartered at Dalhousie University in Halifax, Nova Scotia, Canada.

OTN's mission is to inform the stewardship and sustainable management of aquatic animals by providing knowledge on their movements, habitats and survival in the context of changing global environments.

Since 2008, OTN has been deploying state-of-the-art ocean monitoring equipment and marine autonomous vehicles (gliders) in key ocean locations and inland waters around the world. OTN's technical capabilities have since expanded with the addition of remotely operated vehicles (ROVs) and side-scan sonar systems.

OTN is changing the way oceans and freshwater systems, and the life that moves within them, are understood. New technologies are providing a window into the underwater world; at the same time, the way this information is stored, managed, shared and visualized is creating and sustaining research networks around the globe.

Knowledge generated through OTN collaborations is used provincially, federally and internationally to help guide the management of valued aquatic species and the sustainable use of ocean and freshwater resources.

Together, the Network and its collaborators are tracking animals, connecting people and transforming oceans management.

Spotted eagle ray. Single Fin Photo/Ocean Image Bank

Highlighted projects

OTN-SUPPORTED PROJECTS AROUND THE WORLD

A global community of researchers is using OTN's infrastructure and analytical tools to track the movements and survival of keystone, commercially important and endangered species.

OTN's worldwide network enables researchers to leverage and build upon existing studies to enhance the collective understanding, management and conservation of migratory animals.

This map contains a selection of high-level summaries—denoted by the numbered markers—which highlight some of OTN's Canadian and international tracking collaborations.

For a full list of OTN-supported projects, visit **MEMBERS.OCEANTRACK.ORG**

1035 PROJECTS

1564 CONTRIBUTORS

357 INSTITUTIONS

327 SPECIES

2495 ACTIVE RECEIVERS

HIGHLIGHTED PROJECTS

1 ARRAY UPGRADES COMPLETED ALONG THE PACIFIC NORTHWEST

Along the Pacific Northwest, between Vancouver Island and mainland British Columbia, a series of three OTN acoustic receiver arrays have been gathering important long-term animal movement data since 2012. These arrays are arranged into 'listening lines' that span ecologically, commercially and culturally significant habitat from the Queen Charlotte Strait down to the Juan de Fuca Strait. They are strategically placed to detect tagged species such as migrating salmonids or globally vulnerable white sturgeon in transit between river and sea. After two years, the work to upgrade these arrays from VR3 receivers to new VR4 units is now complete. VR4s have a longer battery life, Bluetooth technology and the ability to detect animals with both 69 kHz and 180kHz tags. The upgrade ensures the arrays will continue to operate optimally, providing essential infrastructure that supports numerous west coast researchers and transboundary fishery collaborations between Canada and the United States.

2 MAKING CONSERVATION CONNECTIONS IN COSTA RICA

The Center for Rescue of Endangered Marine Species (Centro de Rescate de Especies Marinas Amenazadas [CREMA]) has been active in Costa Rica since 1998 with the goal of promoting sustainable management of marine species in the country. With support from OTN's equipment loaner program, CREMA has expanded its monitoring efforts in recent years. Off the coast of mainland Costa Rica, CREMA is using acoustic telemetry to monitor the abundance and habitat use of tagged manta rays and hawksbill sea turtles. Meanwhile, offshore in Cocos Island National Park, CREMA is studying migratory species such as the heavily fished hammerhead shark. Data gathered will assist with marine resource management alongside the region's growing marine protected area (MPA) system, which was recently expanded as part of the Eastern Tropical Pacific Marine Corridor (CMAR) initiative between Costa Rica, Panama, Ecuador and Colombia.

3 Cownose ray

3 BRIDGING KNOWLEDGE GAPS ON COWNOSE RAYS IN THE GULF OF MEXICO

Located in the Gulf of Mexico, Apalachicola Bay is a large and productive estuary that is home to the Atlantic cownose ray. This species has one of the slowest growing populations of any fish, making them vulnerable to overexploitation. Cownose rays were once implicated in the declines of the commercial scallop and oyster fisheries in the region, prompting a culling of the species despite little evidence to support this claim. Their movements in the Gulf and interactions with bivalves remain poorly understood. Researchers at Florida State University are working to fill these knowledge gaps with the help of OTN's tracking infrastructure. As part of the Florida Atlantic Coast Telemetry (FACT) Network, this project increases acoustic detection coverage, providing details about the movement, behaviour and habitat use of cownose rays in this highly significant estuary to support conservation and management.

4 **Green sea turtle.** Gabriel Barathieu/Ocean Image Bank

4 TELEMETRY FOR TURTLE TRACKING IN FLORIDA

Across the globe, OTN's tracking infrastructure supports research on six sea turtle species. Green sea turtles are the species of focus for the Inwater Research Group (IRG) in two different areas along Florida's southeastern coastline—Boca Raton Reef and Hutchinson Island. IRG is using acoustic telemetry to help mitigate threats to green sea turtles by better understanding their movements and interactions with coastal developments, including a fishing pier and power plant, as well as with other associated human activities such as recreational fishing entanglements.

5 TAKING ACTION ON ST. LAWRENCE RIVER FISH MONITORING

The St. Lawrence River is one of the largest and most ecologically significant river systems in the world, connecting the Great Lakes and the Atlantic Ocean. Collaborators with Fisheries and Oceans Canada (DFO) are using OTN acoustic receivers to expand existing monitoring work on the movements of many fish species, including those that travel between fresh and saltwater to complete part of their life cycles (e.g. American eel, striped bass, Atlantic salmon and Atlantic sturgeon). This research on migration, habitat use and other factors influencing fish movement will feed into conservation and management initiatives within the St. Lawrence Action Plan.

6 **Atlantic sturgeon being tagged in the Minas Basin.** Nicolas Winkler Photography, courtesy of FORCE.

6 A COLLABORATIVE APPROACH TO ASSESSING TIDAL POWER IN THE MINAS PASSAGE

In Nova Scotia, the Fundy Ocean Research Centre for Energy (FORCE) is testing instream tidal turbines in the Minas Passage—a narrow connection between the Minas Basin to the rest of the Bay of Fundy. It has been estimated that around 70 fish species travel through the Minas Passage, including Atlantic salmon, Atlantic herring, alewife, striped bass and Atlantic sturgeon. As part of the Fundy Advanced Sensor Technology program, FORCE provides moorings that monitor current speed and turbulence, ambient noise and water quality, as well as host OTN receivers to detect tagged animals. FORCE also maintains an array of receivers on loan from OTN as part of the Risk Assessment Program—a collaborative initiative between FORCE, OTN, the Mi'kmaw Conservation Group, Acadia University and DFO. This research will be used to assess the potential impact of instream tidal power on the surrounding environment, as well as possible interactions between tidal turbines and marine life.

7 MONITORING THE GULLY MPA

Teeming with a diversity of marine life, the Gully MPA lies 200 kilometres off the coast of Nova Scotia. OTN collaborators with the Atlantic Halibut Council, DFO and Acadia University have previously deployed an acoustic receiver array near the Gully—a known hotspot for juvenile Atlantic halibut. To complement ongoing tagging and tracking work for halibut in the area, the existing receiver network has been further expanded to include a 15-kilometre array through a portion of the Gully, which will help researchers to better understand regional connectivity between the hotspot and MPA. These additional receivers ensure complete coverage for each of the current MPAs within the Scotian Shelf Bioregion, while offering insights into the movements of additional tagged species and providing an opportunity to demonstrate connectivity between other conserved areas in the network.

8 DRIFTING FOR SALMON DATA OFF NORTHERN NEWFOUNDLAND

OTN and partners with the Environmental Studies Research Fund undertook the first operational deployment of a new tracking technology—a series of 10 drifting buoys, known as drifters, off Newfoundland's northern coast to track acoustically tagged Atlantic salmon during their feeding migration. Designed to monitor sea surface currents and temperatures, the MetOcean iSVP surface drifters had been previously modified in collaboration with the Atlantic Salmon Research Joint Venture to carry acoustic receivers that detect tagged fish and transmit data via satellite to researchers in real-time. The information gathered during the four-month mission will improve understanding of how Atlantic salmon use marine areas off Eastern Canada. While drifters are not typically retrieved from the water, ocean currents sent two inshore near Placentia Bay after Hurricane Fiona, where OTN recovered the units. The drifters will be examined and refitted by the manufacturer with the intent of redeployment, while the remaining units continue collecting data at sea.

9 NEW HEIGHTS IN THE CANADIAN ARCTIC

In collaboration with researchers at the University of Windsor, an extensive long-term acoustic monitoring program in key coastal and offshore regions of Baffin Bay in the eastern Canadian Arctic continues to grow. The project focuses on stock connectivity of Greenland halibut in a joint effort with local Inuit, the Government of Nunavut, commercial fishers and DFO. This work also examines ecosystem interactions with other tagged species, including Greenland shark, Arctic skate and Arctic cod. Recently, a Slocum glider joined the Arctic monitoring team, along with researchers from the University of New Brunswick and Dalhousie University, to survey waters near the Disko Fan Conservation Area, where they identified Greenland halibut tags, including some that had been discarded by fishing trawlers. The glider also transited 160 kilometres across the Davis Strait to await recovery off Qikiqtarjuaq, Nunavut. This marks the highest latitude reached by one of OTN's gliders—an important milestone as OTN assesses feasibility and performance for future glider operations in Baffin Bay.

10 KEEPING TRACK OF ARCTIC CHAR IN MARINE AND FRESHWATER ECOSYSTEMS IN GREENLAND

In southwestern Greenland, OTN collaborators with the Norwegian University of Science and Technology deployed 36 receivers to study Arctic char in the marine fjord Tasermiut and Lake Tasersuaq. Their research combines acoustic telemetry, stable isotope analysis and DNA sampling to gather baseline knowledge about the movement and temperature preferences of Arctic char in both marine and freshwater environments. Arctic aquatic ecosystems are highly vulnerable to climate change. By studying top predators such as Arctic char, researchers will gain better understanding of ecosystem health and functioning.

10 **Recovering acoustic receivers after a one year deployment in the Greenlandic fjord Tasermiut (left to right: Adam Piper, Jan Grimsrud Davidsen).** Copyright Per Gatzschmann

11 INVESTIGATING PREDATOR-PREY INTERACTIONS IN DENMARK

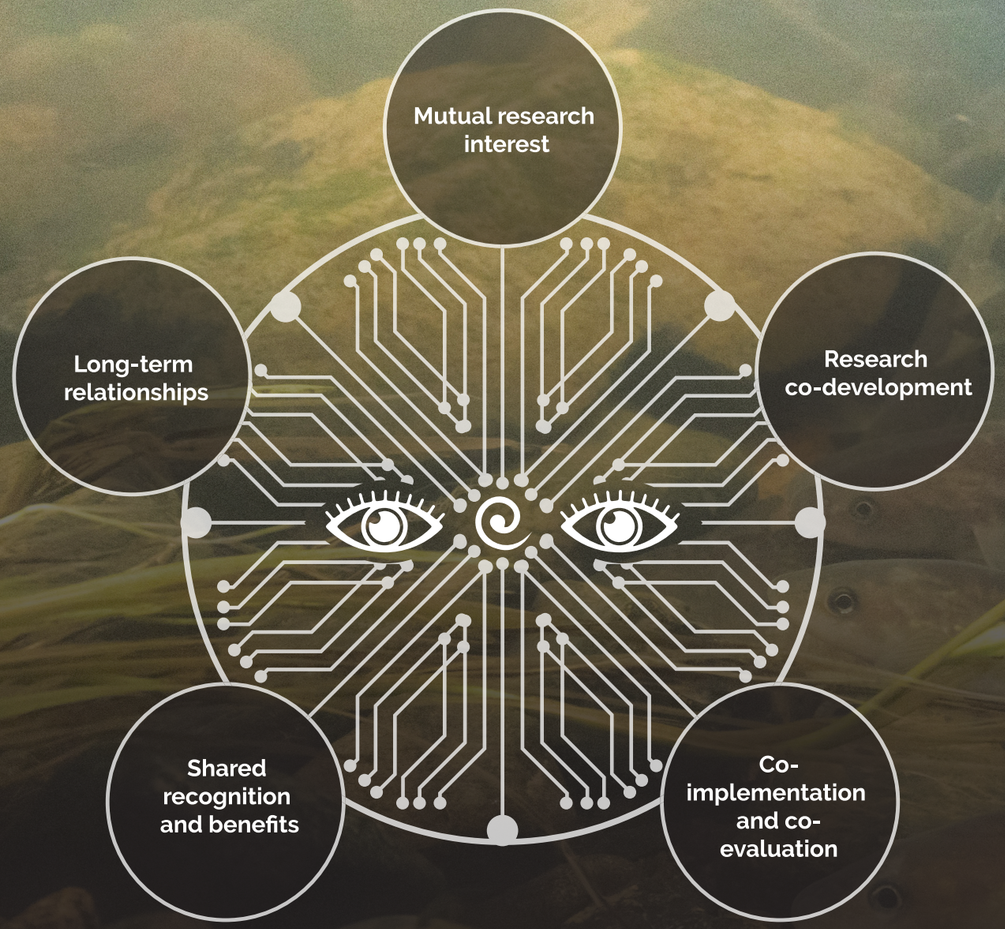
Researchers at the Technical University of Denmark are investigating a pressing topic in the field of acoustic telemetry by testing the 'dinner-bell hypothesis', which suggests that fish tagged at acoustic frequencies within the hearing capacity of most marine animals (69 kHz) will experience higher predation rates than fish tagged at acoustic frequencies outside their hearing capacities (180 kHz). This involves tagging a prey species, brown trout, at different acoustic frequencies, and a predator species, harbour seal, using Vemco Mobile Transceivers (VMTs) in the Limfjord—an enclosed fjord system. VMTs act as both a transmitter and a receiver, allowing researchers to track animal associations and quantify predator-prey interactions.

12 MARINE MEGAFAUNA ON THE MOVE IN MOZAMBIQUE

The coastline of Mozambique's Inhambane province is a globally significant area for migratory marine megafauna. OTN collaborators with the Marine Megafauna Foundation (MMF) have been active here for more than 20 years, working to safeguard the waters for marine populations that are under increasing pressure from fishing activity. MMF is expanding the Inhambane Seascape Array—currently spanning 20 per cent of the Mozambican coast—with the addition of 15 OTN acoustic receivers that will fill current gaps in coverage, providing more insights into the movement of tagged species, including reef manta rays, bull sharks, smalleye stingrays and whale sharks.

12 **Manta ray.** Grant Thomas/Ocean Image Bank

ETUAPTMUMK / TWO-EYED SEEING



This graphic has been adapted from "Two-Eyed Seeing": An Indigenous framework to transform fisheries research and management" published by Reid et al. (2022) in the *Fish and Fisheries* journal.

Atlantic tomcod spawning season in the Shubenacadie River.
Nicolas Winkler Photography

PROJECT SPOTLIGHT

APOQNMATULTI'K

INTEGRATIVE KNOWLEDGE. COLLABORATIVE STEWARDSHIP

After four years of relationship building and co-learning, the first phase of the collaborative research project, Apoqnmatulti'k, is coming to a close. Guided by the Mi'kmaw principle of Two-Eyed Seeing, the project brought together Mi'kmaw, local and western scientific knowledge holders to investigate the movements and habitat use of American eel (katew), American lobster (jakej) and Atlantic tomcod (punamu) in the Bay of Fundy (Pekwitapa'qek) and Bras d'Or Lake (Pitu'pa'q). However, the project quickly evolved into a transformative learning process with impacts extending far beyond the original research objectives.

Conceptualized by Mi'kmaw Elder Albert Marshall, Two-Eyed Seeing (Etuaptmumk) refers to learning to see from one eye with the strength of Indigenous knowledge and ways of knowing, and from the other eye with the strength of western knowledge and ways of knowing.

Two-Eyed Seeing requires space for co-learning and co-development through respectful dialogue. In keeping with this principle, all aspects of Apoqnmatulti'k have been co-developed—from project governance to communication outputs, to knowledge co-production and capacity-building, which have all been central to the project.

Drawing on the strengths of Mi'kmaw, local and western knowledge systems—and learning to see with both eyes—has the potential to transform decision-making and fisheries management.

Skyler Jeddore (UINR), Blair Baker (Baker Blue Ocean) and Nathan Glenn (OTN) on a field mission in the Bras d'Or Lake, Cape Breton. Nicolas Winkler Photography

LESSONS LEARNED

Below, several partners reflect on the project and share their advice for researchers interested in pursuing similar collaborations.

1. *"Involve all partners from the beginning to develop shared research goals and identify the needs of different user groups. With Apoqnmatulti'k, we worked with Mi'kmaw communities, local fishers and academia, as well as Fisheries and Oceans Canada, to really understand the information gaps and how we could work together to fill them. We were all part of the project from the outset, which made for a truly participatory collaboration."* (Sara Iverson, Scientific Director, Ocean Tracking Network)

2. *"Identify key knowledge holders and value their expertise. For example, fishers are on the water all the time. We observe so much about the natural world, but our knowledge is often overlooked or dismissed by academia. This weakens the quality of research being done and decreases the trust the fishing community has in its results. When everyone comes together, we increase respect for one another's knowledge and deepen our shared understanding of the natural world. This is how we achieve true wisdom."* (Darren Porter, Fisher, Bay of Fundy)

3. *"Accept that conflicts will arise and commit to working through them respectfully. Two-Eyed Seeing expects you to leave your comfort zone and explore another way of interpreting the world around you. When we do this, our knowledge systems will collide. Instead of walking away from those collisions, embrace them as an opportunity to learn from one another and move forward together."* (Shelley Denny, Director of Aquatic Research and Stewardship, Unama'ki Institute of Natural Resources)

4. *"Be open to changing your thoughts and beliefs and rethink what you have been taught to be true. Working on this project has impacted the way I conduct research by encouraging me to really question myself and the position I hold. I have had to confront how I perceive the world and what has influenced my perceptions, practices and beliefs. Ultimately, this has allowed me to grow as a student and become a better scientist."* (Shannon Landovskis, M.Sc. Student, Dalhousie University)

5. *"Take the time to develop trust and learn how to work together. Don't let yourself be pressured to rush that process. It takes time to build relationships. We had a huge learning curve in terms of understanding, listening and respecting and had some bumps and bruises along the way, but I think it made our relationship stronger. It made for a better partnership and a better project."* (Alanna Syliboy, Culture, Education & Engagement Manager, Confederacy of Mainland Mi'kmaq)

Darren Porter, Erica Porter and their crew fishing in the Minas Basin.

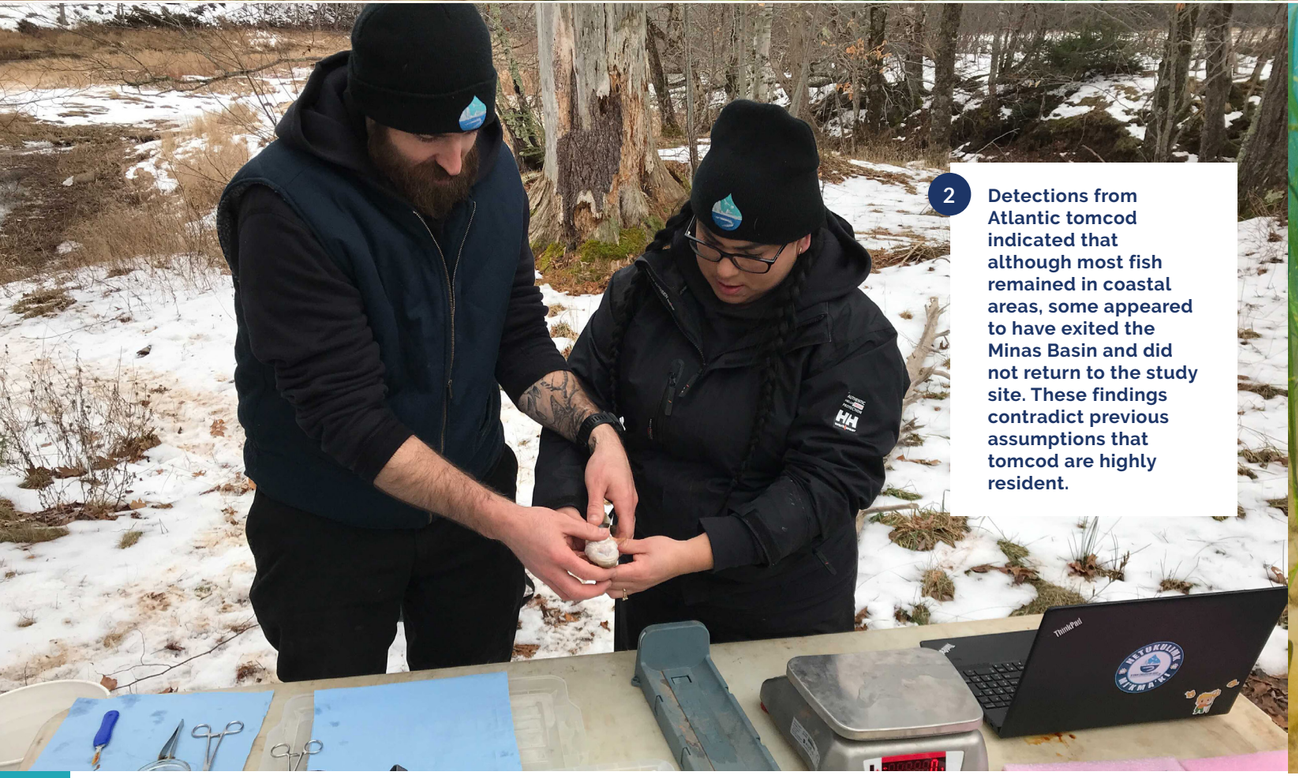
APOQNMATULTI'K DISCOVERIES

Throughout the project, researchers discovered critical knowledge to help inform future aquatic stewardship.

Here are a few highlights:

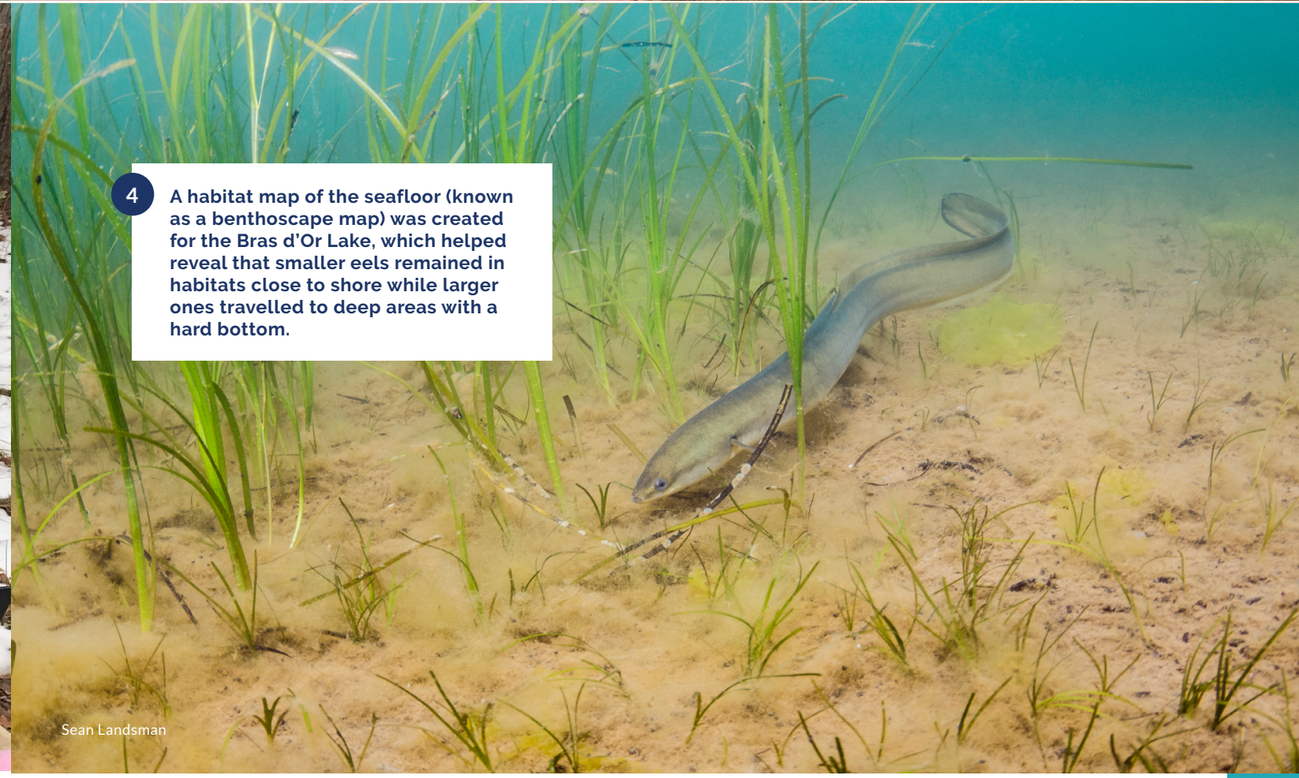
Scott Leslie

1 The East Bay, Bras d'Or Lake, is an ecological boundary for American lobster. Within this area, they utilize different habitat types, such as sand, mud or pebbles, depending on their age.



2 Detections from Atlantic tomcod indicated that although most fish remained in coastal areas, some appeared to have exited the Minas Basin and did not return to the study site. These findings contradict previous assumptions that tomcod are highly resident.

3 With the help of local fishers Erica and Darren Porter, more than 50 eel were tagged in the Minas Basin watershed. These detections revealed that tagged eel use tides to travel between the basin and connecting river systems. They ascend upwards in the water column at high tide and travel into the Avon River and downstream into the Minas Basin during low tide.



Sean Landsman

4 A habitat map of the seafloor (known as a benthoscape map) was created for the Bras d'Or Lake, which helped reveal that smaller eels remained in habitats close to shore while larger ones travelled to deep areas with a hard bottom.

OUTREACH

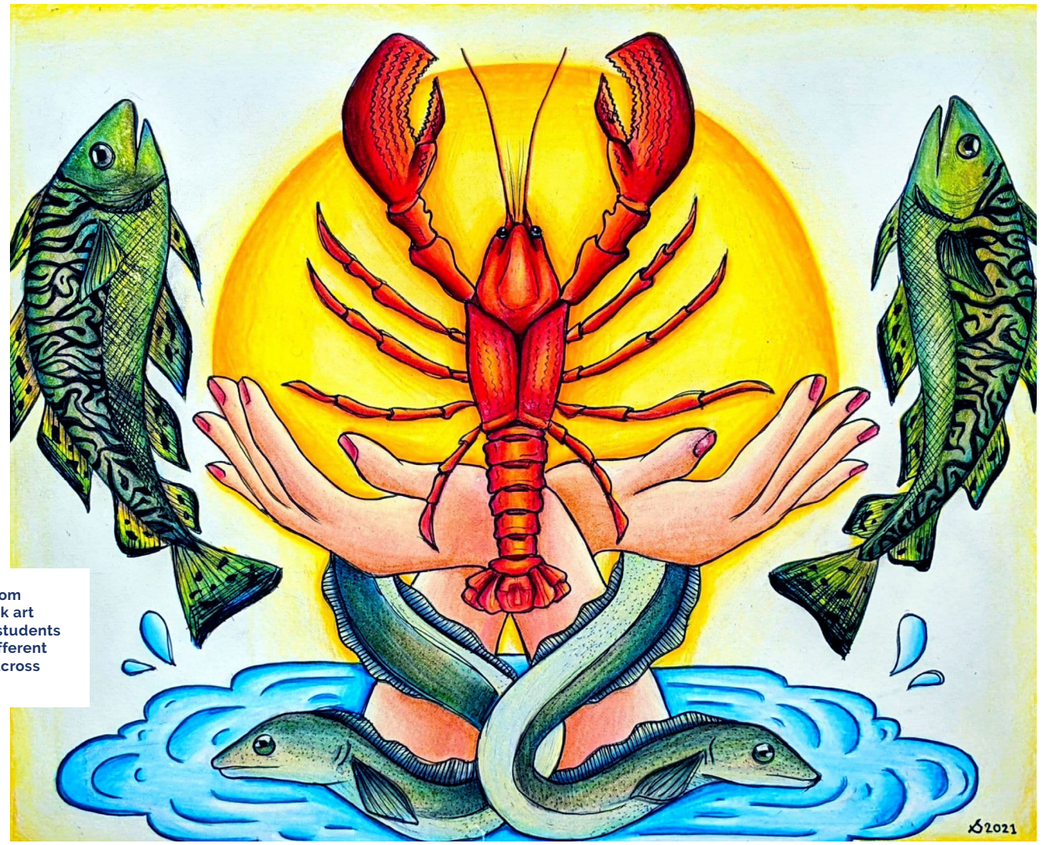
Apoqnmatulti'k utilized various communication channels to share the research process and findings with a diverse and ever-growing audience.

1.1K+ Facebook followers, reaching 75K individuals

5.6K+ people reached with three webinars

597K+ reached in podcasts featuring Apoqnmatulti'k

845K+ reached in online magazines featuring Apoqnmatulti'k



The winning drawing from the 2021 Apoqnmatulti'k art contest. Four hundred students participated from 21 different schools in Grades 6-9 across Nova Scotia.

NEXT STEPS

Perhaps the truest sign of the project's success is the willingness and enthusiasm from collaborators to continue to work together. As the current funding cycle winds down, project partners are already turning their eyes toward the future. This past fall, the partners submitted an application to the project's primary funder, the Natural Sciences Engineering and Research Council of Canada (NSERC) for a five-year Alliance grant for 2023-2028 to continue building upon the scientific findings and partnerships forged, extend the time series critical to assessing changing environments, and introduce several new study species of importance to Mi'kmaw and local communities in Nova Scotia.

Atlantic tomcod. Nicolas Winkler Photography

Tomcod nets in the Shubenacadie River. Nicolas Winkler Photography

Gliders

Gliders are a safe, energy-efficient tool for understanding life underwater and are used in several areas of OTN's research, including servicing moored equipment—primarily acoustic receivers—monitoring for tagged animals, listening for whale calls, and providing additional monitoring capacity for climate, weather and oceanographic scientists. OTN operates the most expansive academic fleet of marine autonomous vehicles in Canada—10 Teledyne Webb Research Slocum gliders and four Liquid Robotics Wave Gliders.

An OTN Teledyne Webb Research Slocum glider deployed off the coast of Nova Scotia. Nicolas Winkler Photography

SLOCUM GLIDERS

OTN's Slocum gliders are electrically powered and spend most of their missions underwater collecting physical, biological and chemical information in the Northwest Atlantic, but have also carried out work in the Arctic and Pacific oceans. These gliders are equipped to detect tagged animals they encounter at sea.

An OTN Teledyne Webb Research Slocum glider. Nicolas Winkler Photography

North Atlantic right whale. Nick Hawkins

NORTH ATLANTIC RIGHT WHALE MONITORING

OTN's collaborative right whale monitoring program marked two major milestones in 2022: eight years of ongoing work, and three years with no reports of North Atlantic right whale deaths in Canadian waters. New partnerships and additional funding have been integral to ensuring the program's success.

In 2021, OTN and Dalhousie University, in partnership with the University of New Brunswick and Transport Canada, initiated a $3.6 million dollar project to continue the monitoring of North Atlantic right whales for five years in the Gulf of St. Lawrence using gliders. The funding also allowed OTN to purchase a new G3s Slocum glider. This robot has been equipped with an upgraded hydrophone that is better integrated into the glider, leading to more streamlined flight.

As part of these monitoring activities, researchers are using DMONs—a type of hydrophone developed by Mark Baumgartner at the Woods Hole Oceanographic Institution—to detect, classify and report the calls and locations of right whales, along with four other species of baleen whales. This information is shared in near-real time to acoustic data analysts who validate the detections and send the information to regulators and vessel operators in busy shipping corridors. Researchers also affix multi-beam echosounders to the gliders to locate occurrences of right whale food (copepods and other zooplankton) within the water column. Results from this ongoing work aim to reduce the number of right whale-ship collisions or entanglements in fishing gear by informing temporary closures, speed limits and vessel rerouting.

With continued support from partners and funders, OTN's gliders are playing a vital role in effectively implementing mitigative measures that are key to protecting this iconic species.

A Slocum glider equipped with a hydrophone that listens for whale calls and a transceiver—a tracking unit that acts as both a transmitter and a receiver.

Nicolas Winkler Photography

An OTN Liquid Robotics Wave Glider. Nicolas Winkler Photography

WAVE GLIDERS

Wave Gliders are solar powered and get propulsion from waves. They collect information on weather, wave height and sea-surface state. OTN primarily uses these vehicles to remotely offload data from bottom-moored tracking stations through a subsurface acoustic modem, or as mobile receiver platforms in areas where anchoring receivers is difficult (e.g. areas subject to intensive bottom dragging). Wave Gliders are a cost-effective, low carbon method for offloading receivers, as they reduce the need to hire vessels to manually collect data from them.

SPRING BLOOM MISSIONS

Every spring, the glider team prepares for the upcoming field season by conducting test missions along the Scotian Shelf between February and April to check the functionality of glider equipment—including sensors—before core missions begin. Together with their colleagues from the Coastal Environmental Observation Technology and Research (CEOTR) group, a collaborative initiative between OTN and the Ocean Frontier Institute (OFI), the glider team uses this testing opportunity to advance oceanographic research.

Since 2019, the glider team has coordinated its test missions with oceanographers—including scientist Dariia Atamanchuk at Dalhousie University and Nova Scotia-based sensor company Pro-Oceanus Systems—to monitor the spring bloom.

With support from OFI and Nova Scotia Business Inc., Dr. Atamanchuk worked with the glider team to integrate new sensors onto a Wave Glider and measure the flux of carbon dioxide in the ocean. This glider was deployed during the tail end of a spring phytoplankton bloom in the Northwest Atlantic—a naturally occurring algae bloom in which phytoplankton, the base of the marine food web, multiply so rapidly that they can be seen from space!

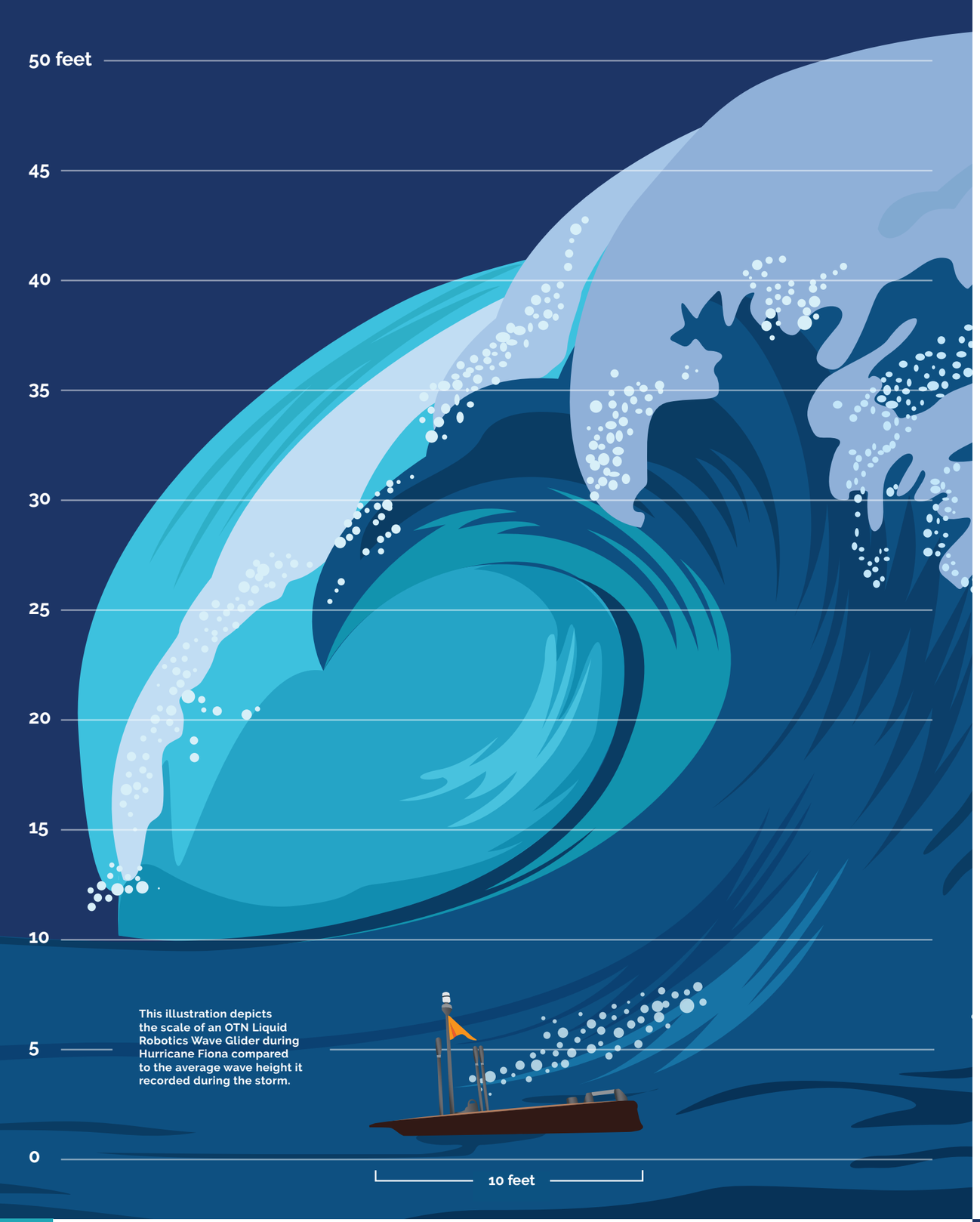
This research will help further understanding of how phytoplankton can draw carbon dioxide into the ocean, potentially helping mitigate some of the impacts of climate change.

TRACKING COD

Since 2016, OTN has been working with industry partners and research institutions on the Northern Cod Acoustic Tracking (NCAT) fishery improvement project in the Northwest Atlantic, led by the Atlantic Groundfish Council and the Association of Seafood Producers.

NCAT partners are using OTN's Wave Gliders and strategically deployed receiver arrays—located along the northeast coast of Newfoundland and Labrador—to track acoustically tagged cod. Paired with genetic sampling and analysis supported by OFI, this monitoring work is helping researchers better understand the movements, population structure and habitat use of Atlantic northern cod.

The NCAT project will continue to collect data for the next five years with the aim of informing and improving the overall long-term management of cod stocks.



This illustration depicts the scale of an OTN Liquid Robotics Wave Glider during Hurricane Fiona compared to the average wave height it recorded during the storm.

WAVE GLIDERS

NEW TECHNOLOGY DEVELOPMENT: OCEAN AWARE HYDROPHONE TESTING

Over the summer, the glider team coordinated with Innovasea under the Ocean Supercluster's Ocean Aware project to affix a new prototype receiver—known as a Mobile-Rx—to a Wave Glider. The goal of the mission was two-fold: to compare the detection efficiency of the new receiver to that of older models, and to test a new mounting design. The glider was programmed to survey an area outside of Sable Island for acoustically tagged halibut, and to perform a dedicated range testing mission to support research for the Atlantic Halibut Council, Fisheries and Oceans Canada (DFO) and Acadia University. Unfortunately, the Wave Glider was damaged in Hurricane Fiona and the bottom unit (also known as a 'sub') that contained the Mobile-Rx was lost. Despite this setback, plans to continue testing the prototype in 2023 are underway. Once the Mobile-Rx is fully developed, it will greatly increase the number of platforms and environments in which acoustically tagged animals can be tracked effectively.

HURRICANE FIONA

OTN's SV3-129 Wave Glider was deployed off Nova Scotia in the fall to monitor DFO's halibut study zone, and while deployed, found itself at the centre of Hurricane Fiona—a Category 4 tropical storm that blew through Atlantic Canada in September (see diagram at left).

During its at-sea mission, the glider recorded maximum winds at 90 knots (nearly 170 kilometres per hour), low atmospheric pressure of 948 millibars and an average wave height of 14-15 metres (almost 50 feet)!

Despite sustaining damage, the glider continued to collect oceanographic measurements during the storm, demonstrating the benefit of being able to send ocean robots such as gliders into extreme weather conditions.

Once the storm had passed, staff safely recovered the glider to assess damage and conduct repairs in preparation for a return to service.

An OTN Liquid Robotics Wave Glider. Nicolas Winkler Photography

The OTN field team

OTN's Halifax Line is made up of 251 acoustic receiver units, making it the world's longest tracking array. These bottom-anchored receiver units stretch from the coast to the Scotian Shelf detecting acoustically tagged species—including blue sharks—that move through the Northwest Atlantic.

Blue sharks are the most common bycatch shark species in commercial high seas and coastal fisheries. A key component of the marine food web, blue sharks keep fish populations and other elements of the ocean ecosystem in balance.

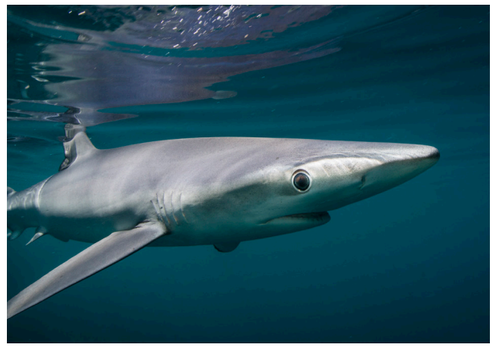
Tagging blue sharks provides insights into the spatial resolution of their movements and distributions, trans-boundary migrations, site fidelity and the species' response to a changing ocean.

Long-term monitoring of this understudied and highly migratory predator is generating data that can better inform conservation measures for the species.

OTN field technicians Cassandra Hartery and Nathan Glenn prepare a Blue Robotics ROV for 'flight'.

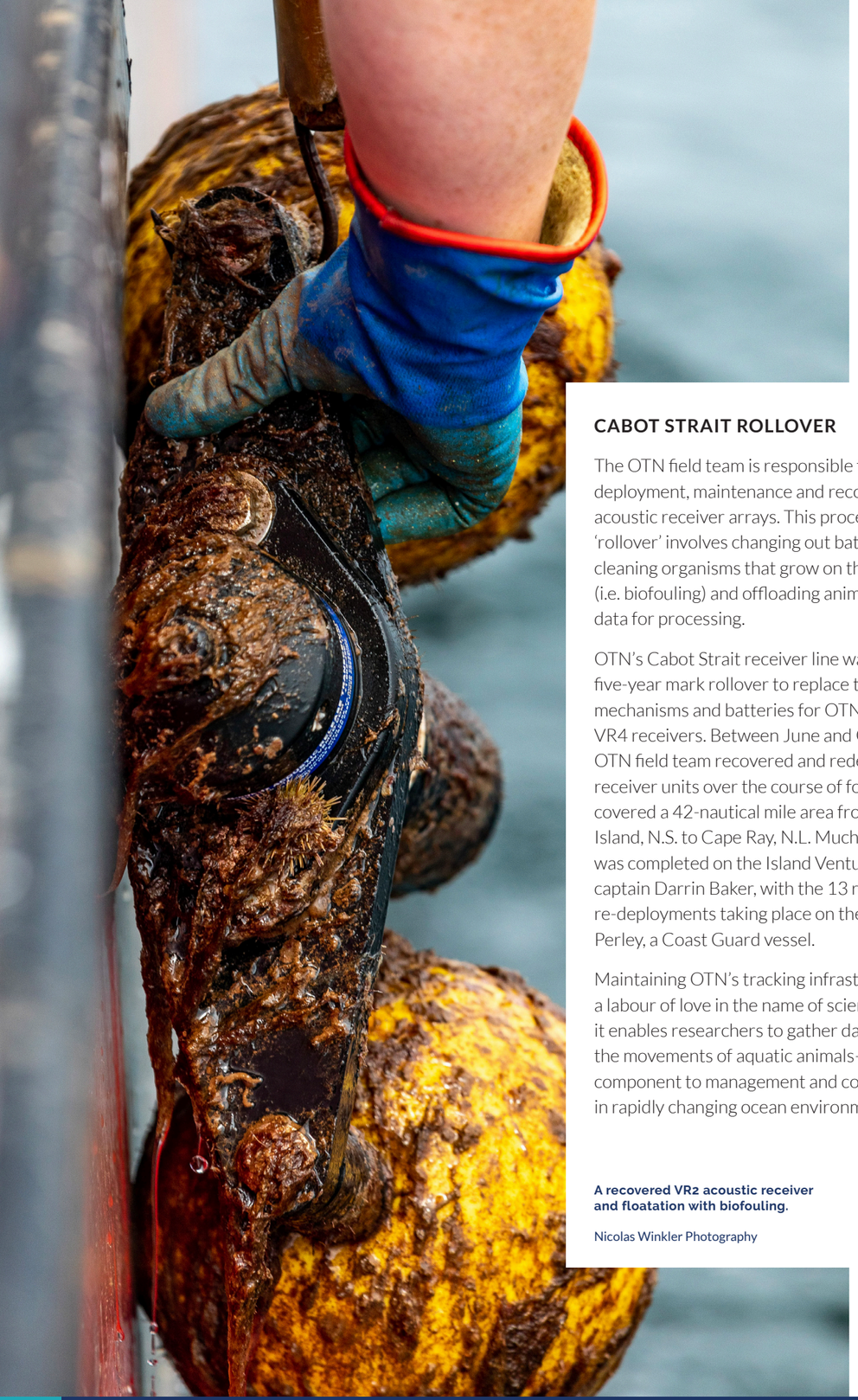
Nicolas Winkler Photography

Blue shark. Ellen Cuylaerts/Ocean Image Bank



In May, field staff deployed OTN's Blue Robotics ROV to survey reef balls in Pictou Landing, N.S.—part of a larger program led by the Mi'kmaw Conservation Group to enhance and restore coastal areas within the Bay of Fundy watershed and the Northumberland Strait.
Nicolas Winkler Photography

An OTN Innovasea receiver moored off Nova Scotia.
Nicolas Winkler Photography



CABOT STRAIT ROLLOVER

The OTN field team is responsible for the deployment, maintenance and recovery of acoustic receiver arrays. This process of a 'rollover' involves changing out batteries, cleaning organisms that grow on the equipment (i.e. biofouling) and offloading animal tracking data for processing.

OTN's Cabot Strait receiver line was due for its five-year mark rollover to replace the release mechanisms and batteries for OTN's Innovasea VR4 receivers. Between June and October, the OTN field team recovered and redeployed 95 receiver units over the course of four trips that covered a 42-nautical mile area from St. Paul Island, N.S. to Cape Ray, N.L. Much of the work was completed on the Island Venture I with captain Darrin Baker, with the 13 remaining re-deployments taking place on the CCGS M. Perley, a Coast Guard vessel.

Maintaining OTN's tracking infrastructure is a labour of love in the name of science, and it enables researchers to gather data about the movements of aquatic animals—a critical component to management and conservation in rapidly changing ocean environments.

A recovered VR2 acoustic receiver and floatation with biofouling.

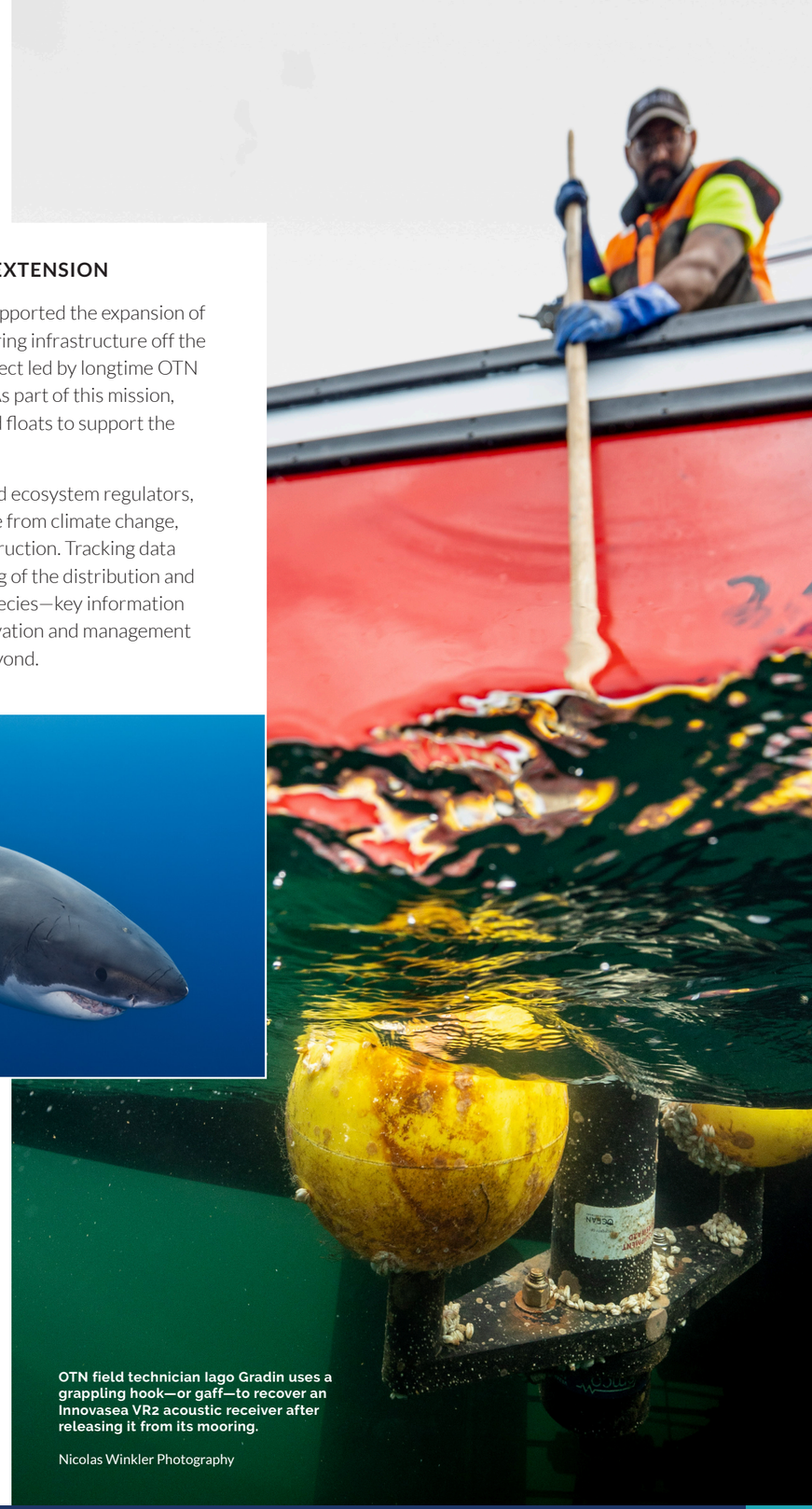
Nicolas Winkler Photography

WHITE SHARK ARRAY EXTENSION

During the summer, OTN supported the expansion of existing white shark monitoring infrastructure off the coast of Nova Scotia—a project led by longtime OTN collaborator Nigel Hussey. As part of this mission, OTN provided moorings and floats to support the 50-station array.

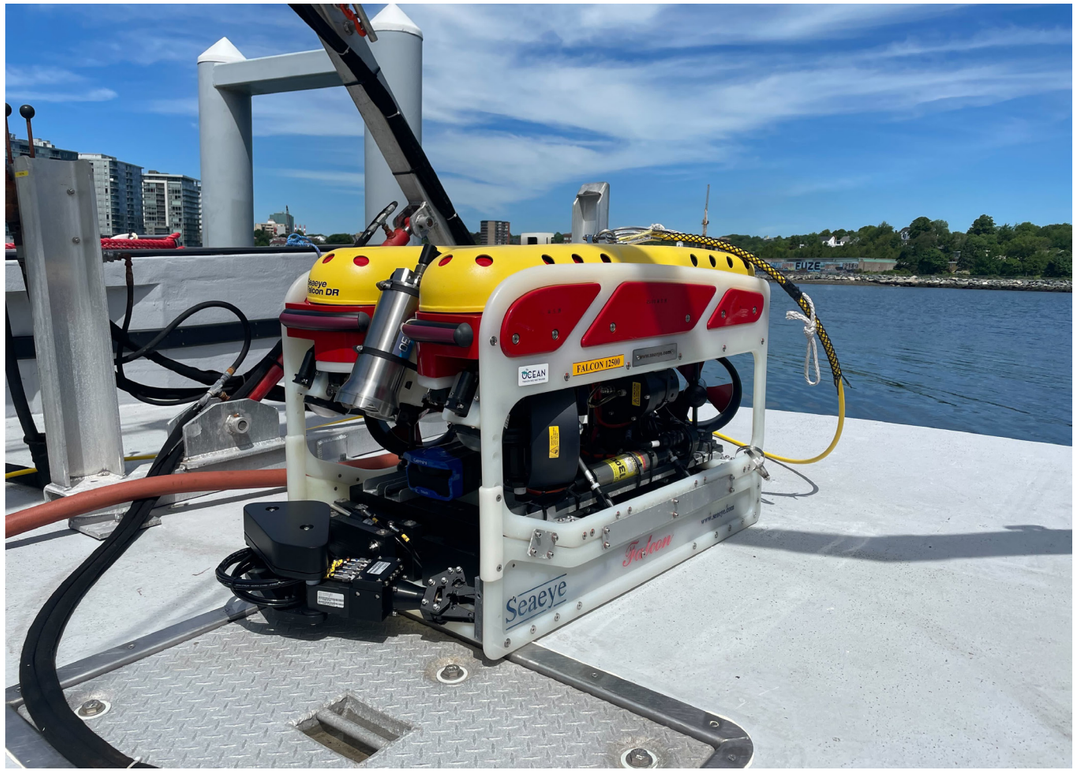
Sharks are top predators and ecosystem regulators, and face increasing pressure from climate change, overfishing and habitat destruction. Tracking data are improving understanding of the distribution and migration patterns of the species—key information in answering critical conservation and management questions in Canada and beyond.

White shark. Andy Casagrande/ Ocean Image Bank



OTN field technician Iago Gradin uses a grappling hook—or gaff—to recover an Innovasea VR2 acoustic receiver after releasing it from its mooring.

Nicolas Winkler Photography



The greater depth capability of the Falcon-DR extends the potential for maintenance and recovery of lost tracking equipment, lends itself to oceanographic and biological surveying, and expands opportunities for OTN's research into deep-water habitats.

FLYING THE FALCON

OTN's capacity for deep-water research expanded in 2020 with the purchase of a Saab Seaeye Falcon-DR remotely operated vehicle (ROV) that has a depth rating of 1000 metres. Features such as a multi-beam sonar, high-definition camera and an ultra-short baseline acoustic positioning system help pinpoint the location of unresponsive equipment. This past year, the OTN field team has been putting this robot to good use by deploying it to find and retrieve equipment stranded in the Northwest Atlantic—including an ice sonar in Cape Breton for partners at Emera Newfoundland and Labrador—as well as nine VR2 acoustic receivers, and one VR4 acoustic receiver. These recoveries are crucial to reducing the loss of expensive gear and preserving irreplaceable oceanographic and animal telemetry data.

SABLE ISLAND WAVE BUOYS

In the spring, OTN, in collaboration with the Ocean Frontier Institute, was involved in the deployment of two wave buoys off Sable Island National Park Reserve.

Using satellite networks to transmit data, the buoys allow for near real-time monitoring of ocean conditions, including wave height, period and swell direction, and will help improve understanding of the hydrodynamic forces behind coastal flooding and erosion on Sable Island.

This monitoring work is part of a larger research initiative through Dalhousie University's Coastal Hydrology Lab to create a wireless sensor monitoring network for the island, making this far-off, isolated place remotely accessible.

The receiver unit—encased in a custom float collar—that became unmoored on the east coast of Canada, crossed the Atlantic and was found by the Barrett family in Conamara, County Galway, Ireland. Barrett family

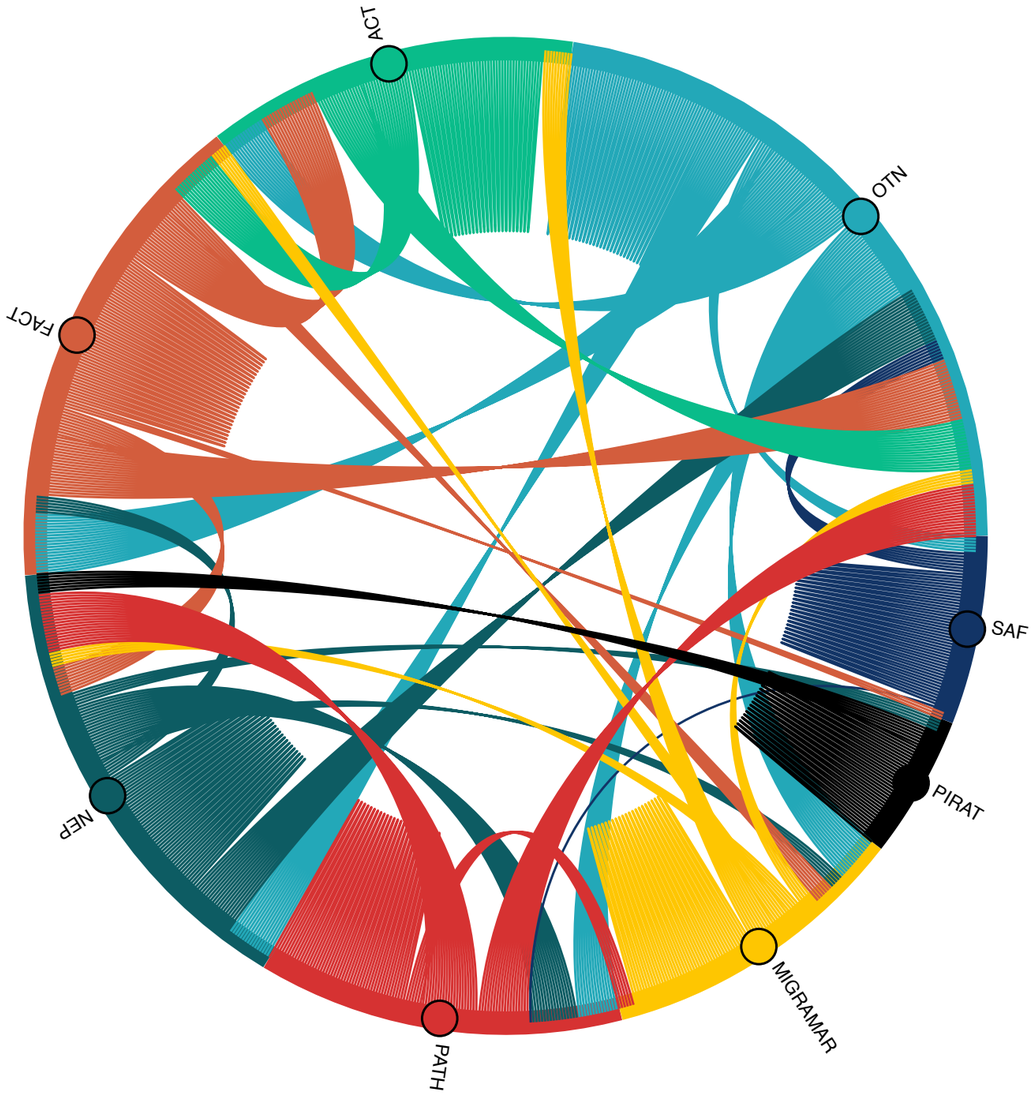
LOST & FOUND: IRELAND BOUND

The Barrett family was combing their local beach in Ireland when they came across a big surprise: an OTN-owned VR4 acoustic receiver that had washed ashore during a recent storm! VR4 receivers are typically deployed at great depths as part of offshore tracking arrays, where they collect important information on the movements of tagged marine animals. Working in an incredibly dynamic environment presents many challenges and sometimes results in the loss of gear. When gear is relocated, OTN staff coordinate with partners in the region to recover the equipment and assess the damage to determine if data recovery is possible.

A grey seal outfitted with tracking equipment and a camera. Damian Lidgard

LOST & FOUND: A PINNIPED'S PERSPECTIVE

In the summer of 2021, two fishers discovered an unusual looking item while harvesting surf clams along Nova Scotia's Banquereau Bank—a digital camera that had been missing since 2019. The camera was affixed to the back of a male grey seal who then journeyed into the Atlantic Ocean with it and never returned. The camera was originally deployed to collect footage on the foraging behaviour of Sable Island seals. Once it was sent to the manufacturer for footage retrieval and returned to OTN investigator and Fisheries and Oceans Canada biologist Damian Lidgard, the camera revealed more than 19 hours of high-resolution footage—including documentation of the seal foraging and chasing females deep beneath the surface! The video is helping researchers uncover new information—as well as confirm previous findings—around grey seal behaviour while at sea.



A plot depicting the number of matched animal detections within and between nodes (log-scaled), demonstrating the interconnectivity of OTN nodes and the degree to which they depend on one another to resolve detections between projects and nodes. Across all compatible nodes, the OTN data system adds dozens of new projects worldwide every year. The data from these new projects aids in filling in detection gaps across the global ocean.

NEP	Northeast Pacific Node
FACT	FACT Network
ACT	Atlantic Cooperative Telemetry Network
OTN	Ocean Tracking Network
SAF	South African Node
PIRAT	Pacific Islands Region Acoustic Telemetry Network
MigraMar	MigraMar
PATH	Pacific Aquatic Telemetry Hub

The OTNDC

Connecting researchers globally

The OTN Data Centre (OTNDC) connects a global community of researchers, teaches open-source data analysis tools and contributes to the development of global data standards. OTN researchers collaborate by virtue of their shared interests, whether by an overlap of the target species across their study areas or through the development of methodologies and tools for data synthesis, analysis and presentation.

OTN partners with several acoustic telemetry networks around the world that work in concert to maintain inter-compatible data nodes. An OTN node is an exact copy of OTN's acoustic telemetry database structure, which allows for direct cross-referencing between the data holdings of each regional telemetry sharing community. This interoperability allows tag detections to be matched across all nodes and increases the likelihood that researchers will receive the detections of their tagged animals outside their own arrays. Since the nodes are created and managed in the same way, researchers only need to submit their project records to one node to receive detections from all nodes. OTN nodes across the globe are managing acoustic and other telemetry data using software and data systems developed and maintained by the OTNDC.

The OTNDC is committed to building, updating and maintaining its public suite of One True Workshop curriculums, based in the inclusive, accessible and proven Carpentries style of pedagogy.

The OTN data team hosted many workshops in 2022, including node manager training sessions, which trained 14 new node managers and attracted 48 attendees from several regions of the globe.

The OTN data team was thrilled to host Aubri Noyez, data manager for the European Tracking Network (ETN), for three days of working meetings in November 2022. These meetings were productive and informed new developments at OTN and ETN, while simultaneously strengthening the connectivity between partner networks and data systems.

WELCOME, PATH & PIRAT!

In 2022, the OTNDC welcomed two new nodes: the Pacific Islands Region Acoustic Telemetry (PIRAT) Network—a collaboration of researchers and partners using acoustic telemetry for the study of aquatic animals in the Pacific Islands Region, and the Pacific Aquatic Telemetry Hub (PATH)—a collaborative data exchange network of data owned by a variety of agencies and institutions curated by UC Davis. Partner nodes and affiliated networks such as PATH and PIRAT have been instrumental in facilitating research cooperation, data sharing and curation across geographic boundaries.

ONE BILLION DETECTIONS MILESTONE

In June, the OTNDC crossed another major milestone by surpassing one billion detections by OTN and compatible partner nodes and networks! With so many telemetry practitioners reporting their data to OTN and its partners—currently and historically—millions of acoustic detections are being matched to their tag owners across the entire network of OTN nodes. New collaborations are being formed by animal telemetry researchers throughout the global ocean, creating connections across OTN's worldwide network.

TOTAL DETECTIONS BY TYPE

OTN and its partner nodes have a total of 807,162,403 detections divided up into the following:

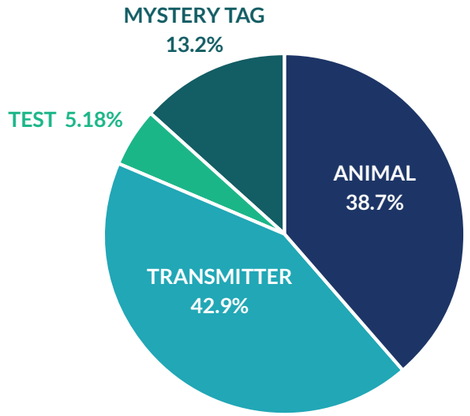
ANIMAL: 374,364,211 These detections are confirmed as belonging to a tagged animal deployed by an OTN-affiliated researcher or data partner.

TRANSMITTER: 415,227,446 These detections are from tags that were deployed in fixed locations (i.e. sentinel tags), or tag codes used by transceiver units (i.e. for inter-receiver synchronization).

MYSTERY TAG: 127,261,032 These detections are not yet associated with any deployed tag.

DATA AGGREGATION ON A GLOBAL SCALE

The OTNDC is participating in two global data aggregation efforts. The first is in support of the International Bio-Logging Society's COVID-19 Biologging Initiative, which is investigating global wildlife responses to altered levels of human activity during the pandemic, with the goal of using animal tracking data collected before, during and after lockdowns to advance understanding of human-wildlife interactions and inform global conservation efforts. The second is in conjunction with the Marine Biodiversity Observation Network's and the Animal Tracking Network's BioTrack initiative—a joint project to integrate, store, process, visualize and share animal tracking data on marine biodiversity hotspots. The original iteration of this program, which focused on aggregating satellite tracking data, has since expanded to incorporate acoustic tracking data—including that of OTN and partner networks—to better characterize these hotspots. OTN also became a founding member of the Animal Borne Sensors (AniBOS) network as part of the Global Ocean Observing System.



TEST: 50,056,844 These detections are of tags that have been identified by manufacturers as reserved for testing purposes only, but for which we have no associated information (i.e. in the case of shipboard testing or sentinel transmitters).

"OTN's study hall was instrumental in helping me write my thesis. The no-judgment atmosphere makes it very easy to ask questions, and with the broad collective knowledge brought to the table by diverse attendees, you're sure to find a solution for the most basic of questions to the most complex of analyses."

– Hunter Stevens, M.Sc., Dalhousie University

STUDY HALL

In the spring, the OTN data team marked two years of hosting weekly virtual study halls to help connect students and early career researchers to data managers, programmers and senior researchers from around the world.

Guest presenters in 2022 included Josh London (NOAA Alaska Fisheries Science Center), author of the the R package, pathroutr, which simplifies the calculation of animal movement paths around land masses, and James Grecian (Durham University, UK), who spoke about using INLA for marine animal movement models.

OTN's study halls have been wildly popular, bringing together a global community to learn about new analysis tools and techniques, help answer telemetry data questions and problem-solve. These online events have even played a key role in the formation of new collaborations and friendships!

For a complete list of OTN database nodes and partners, visit **MEMBERS.OCEANTRACK.ORG**

Leopard shark. Jake Wilton/Ocean Image Bank

Events & activities

Southern stingray. Gregory Piper/Ocean Image Bank

Hubert Saulnier, Tonya Wimmer, Delphine Durette Morin, Fred Whoriskey and Sean Brillant at the Central Library in Halifax, N.S.

On June 8, OTN and the Canadian Wildlife Federation hosted a free public screening of the HitPlay Productions award-winning doc, ***Last of the Right Whales***, which played at the Halifax Central Library as part of World Oceans Day. The film tells the story of a passionate group of people—a wildlife photographer, a marine biologist, a whale rescuer and a crab fisher—united in their cause to save this critically endangered species. The evening included a question-and-answer period with Fred Whoriskey (OTN), Hubert Saulnier (fisher), Tonya Wimmer (Marine Animal Response Society), Delphine Durette Morin (Canadian Whale Institute) and Sean Brillant (Canadian Wildlife Federation).

In the spring, OTN and SuperNOVA at Dalhousie University hosted interactive booths at the Alderney Landing Farmers' Market as part of **Science Odyssey's** Science Rendezvous—a nation-wide festival that takes science from the lab and into community spaces. OTN staff talked to marketgoers about the technology of aquatic animal tracking, 'flew' an ROV in Halifax Harbour and even displayed a Slocum glider for interpretation!

OTN joined **Back to the Sea Society** in downtown Dartmouth and spoke with more than 40 visitors, including a local summer camp, about the technology behind exciting research projects taking place in Atlantic Canada and beyond.

For the fifth consecutive year, OTN teamed up with the **Terranaut Club**—an accessible science exploration club for girls in Atlantic Canada and South Florida. OTN staff hosted a session on aquatic telemetry and the role of gliders in collecting tracking and oceanographic data and facilitated a tour of the COVE glider space!

LEFT Nathan Glenn and Fiona Lynch from OTN's field team at the Science Rendezvous ocean sciences showcase in Dartmouth, N.S., Canada.

BELOW From left to right: CEOTR team lead Richard Davis, OTN glider technician Laura Raposo and OTN field operations and data acquisition coordinator Caitlin Bate presenting to the Terranaut Club in Dartmouth, N.S., Canada.

Fiona Lynch, an OTN field technician and ROV specialist, guides ECRs through the operation of the Falcon-DR during OTN's 10th symposium.

OTN SYMPOSIUM 2022

The 2022 OTN Symposium brought more than 120 researchers and highly qualified personnel (HQP) from across the world to Halifax, Nova Scotia to talk about the latest developments in aquatic animal tracking. This hybrid event featured virtual and in-person panel discussions, and marked the first time that OTN's national and international networks have been able to gather face-to-face since 2019. Mi'kmaw Elder Albert Marshall provided a keynote address on Two-Eyed Seeing (Etuaptmumk), which was followed by a panel on building strong Indigenous research partnerships. Participants also discussed international research programs, navigating the science-policy interface and advances in glider and associated technologies. After the main events had concluded, OTN hosted a full-day workshop for early career researchers (ECRs) and HQP.

Sessions on managing data, researcher positionality and scientific illustrations provided hands-on training, while a tour of Dalhousie University's Aquatron facilities showcased some of the technology—including the Saab Seaeye Falcon-DR ROV—helping to drive marine research in Atlantic Canada. The 2022 OTN Symposium was made possible thanks to sponsorship from Innovasea, Emera Newfoundland and Labrador, Liquid Robotics, Atlantic Halibut Council, the Atlantic Groundfish Council and Association of Seafood Producers with the Northern Cod Fishery Improvement Project, Teledyne Marine and Lotek.

The Marine Animal Response Society (MARS) team caring for a live stranded juvenile long-finned pilot whale. MARS is one of many recipients of Tag! You're It! funding.

Simon d'Entremont

Tag! You're It!—OTN's conservation partnership with Big Spruce Brewing—entered its sixth year. The white shark image featured on the 2022 can symbolizes the work being undertaken by organizations—including OTN and its partners—to monitor and conserve top predators in the marine environment. Conservation financing efforts will be directed to multiple species and organizations in support of healthy ocean ecosystems. Since its inception in 2017, the colla'beer'ation has raised nearly $130,000 and counting for Canadian conservation initiatives!

The 2022 Tag! You're It! can design.

Blue shark. Hannes Klostermann/Ocean Image Bank

INNOVATION Canada Foundation for Innovation Fondation canadienne pour l'innovation

NSERC CRSNG

RESEARCH NOVA SCOTIA

Fisheries and Oceans Canada Pêches et Océans Canada

Transport Canada Transports Canada

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