OCEAN TRACKING NETWORK

OTN

THE FIRST 10 YEARS

“The sea, once it casts its spell,
holds one in its net of wonder forever.”

JACQUES COUSTEAU

PHOTOGRAPH BY SEAN LANDSMAN

A tiger shark investigates an OTN station deployed by University of Miami collaborators in the Bahamas.

PHOTOGRAPH BY JIM ABERNETHY, JIM ABERNETHY'S SCUBA ADVENTURES

Track. Connect. Transform.

For the past 10 years, the Ocean Tracking Network (OTN) has been changing the way we understand our ocean and the life that moves within it. 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 revealing networks around the world. Together, these developments are shifting the paradigm of global oceans management. This report reflects on some of OTN's transformative work.

No attempt to unite world aquatic telemetry activity had been undertaken before OTN accepted the challenge. Responsibilities for creating and housing the OTN headquarters and staff, establishing binding collaboration agreements with a vast array of international partners, and servicing the administrative needs of a network with global reach and unique needs was made possible by Dalhousie University. Dalhousie, with its long history as a major ocean research institution, was uniquely qualified for the task. The institution's knowledge of how ocean research gets done, coupled with the professional services available in its legal, purchasing, research services, finance, human resources and other fields, were instrumental in making the first 10 years of OTN a success.

PHOTOGRAPH COURTESY OF DALHOUSIE UNIVERSITY

ABOUT OTN

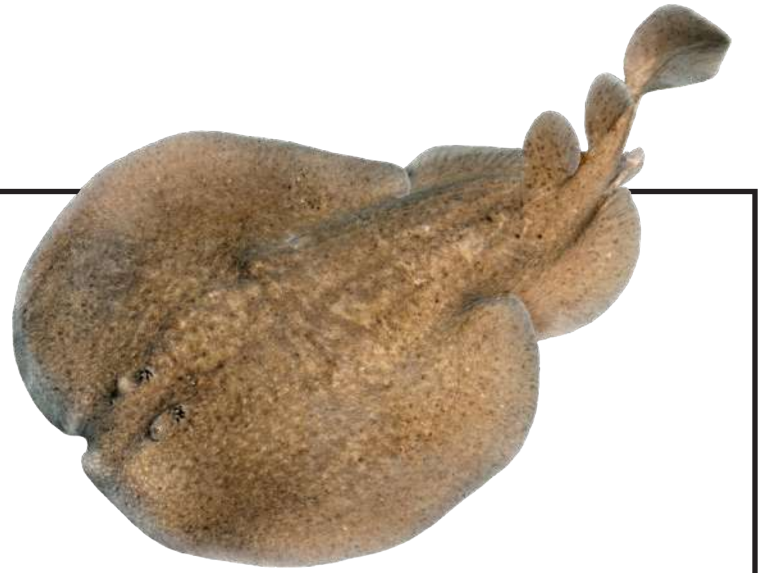
The **Ocean Tracking Network** is a global aquatic research, data management and partnership platform headquartered at Dalhousie University in Halifax, Nova Scotia, Canada.

ABOUT OTN

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.

The Ocean Tracking Network/Marine Environmental Observation Prediction and Response Network (MEOPAR) glider crew deploys a Wave Glider on a mission in Atlantic Canada.

PHOTOGRAPH COURTESY OF MEOPAR



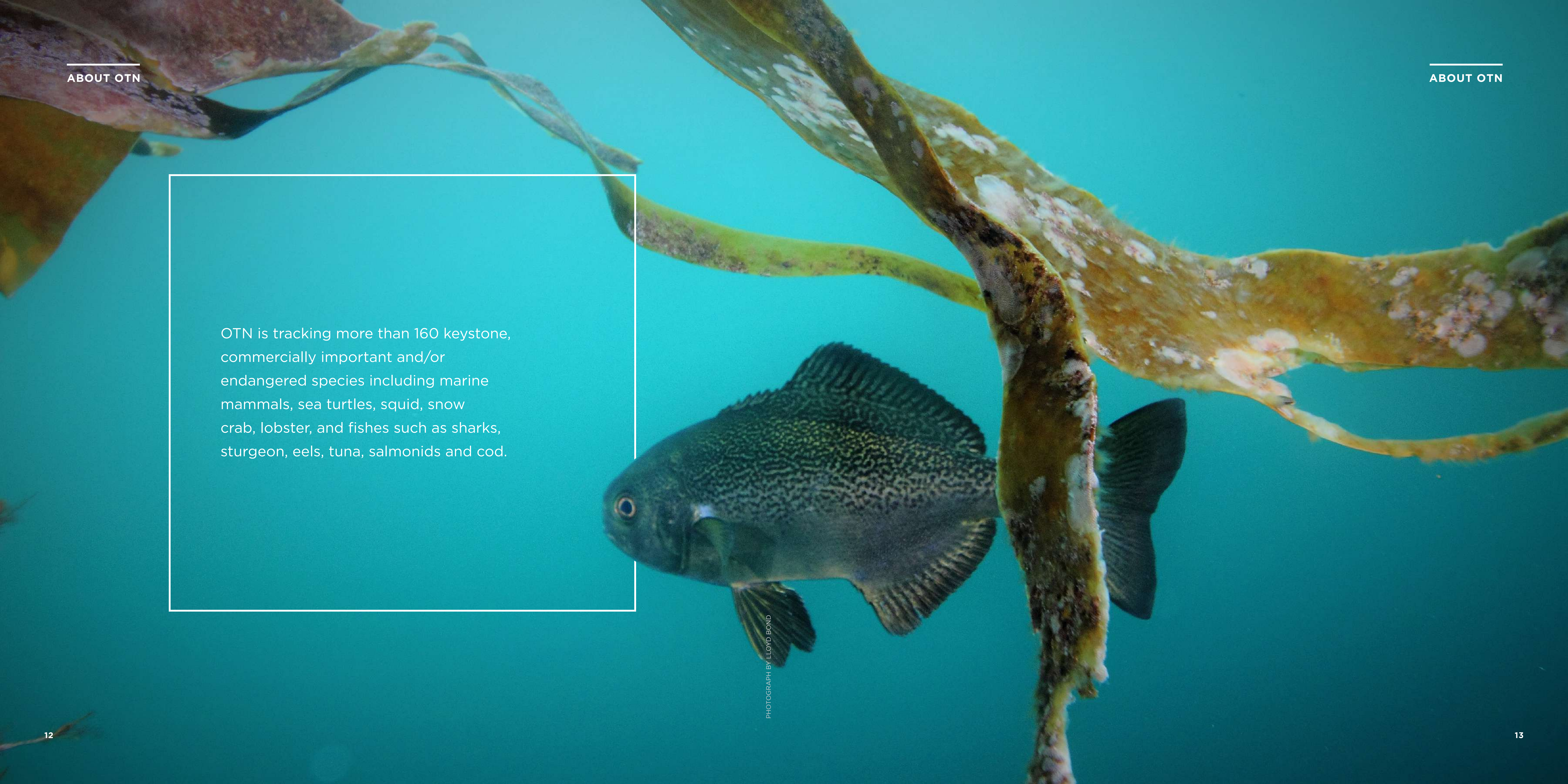
OTN has established partnerships with a global community of telemetry users and stakeholders to document the movements and survival of aquatic animals in the context of changing ocean environments.

Canada's Science Minister, the Honourable Kirsty Duncan (second from right), and Halifax MP Andy Fillmore (right) tour the Steele Ocean Sciences Building and learn about OTN/MEOPAR gliders.

PHOTOGRAPH COURTESY OF DALHOUSIE UNIVERSITY

Knowledge generated by OTN is used by scientists, managers, policy-makers, industry, Indigenous and coastal communities and the general public.

ABOUT OTN



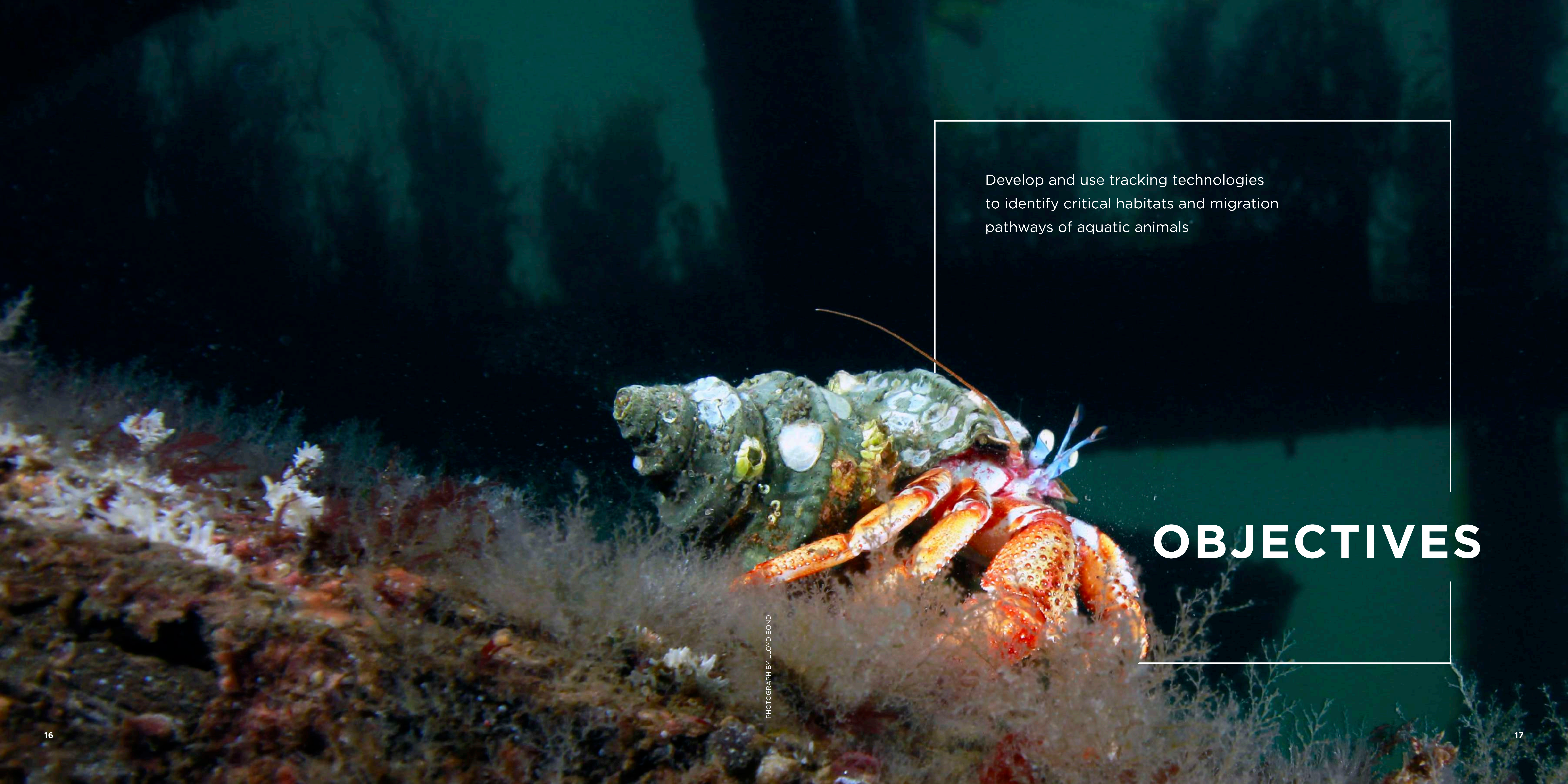
OTN is tracking more than 160 keystone, commercially important and/or endangered species including marine mammals, sea turtles, squid, snow crab, lobster, and fishes such as sharks, sturgeon, eels, tuna, salmonids and cod.

PHOTOGRAPH BY LLOYD BOND


PHOTOGRAPH BY MATT CASSELMAN

MISSION

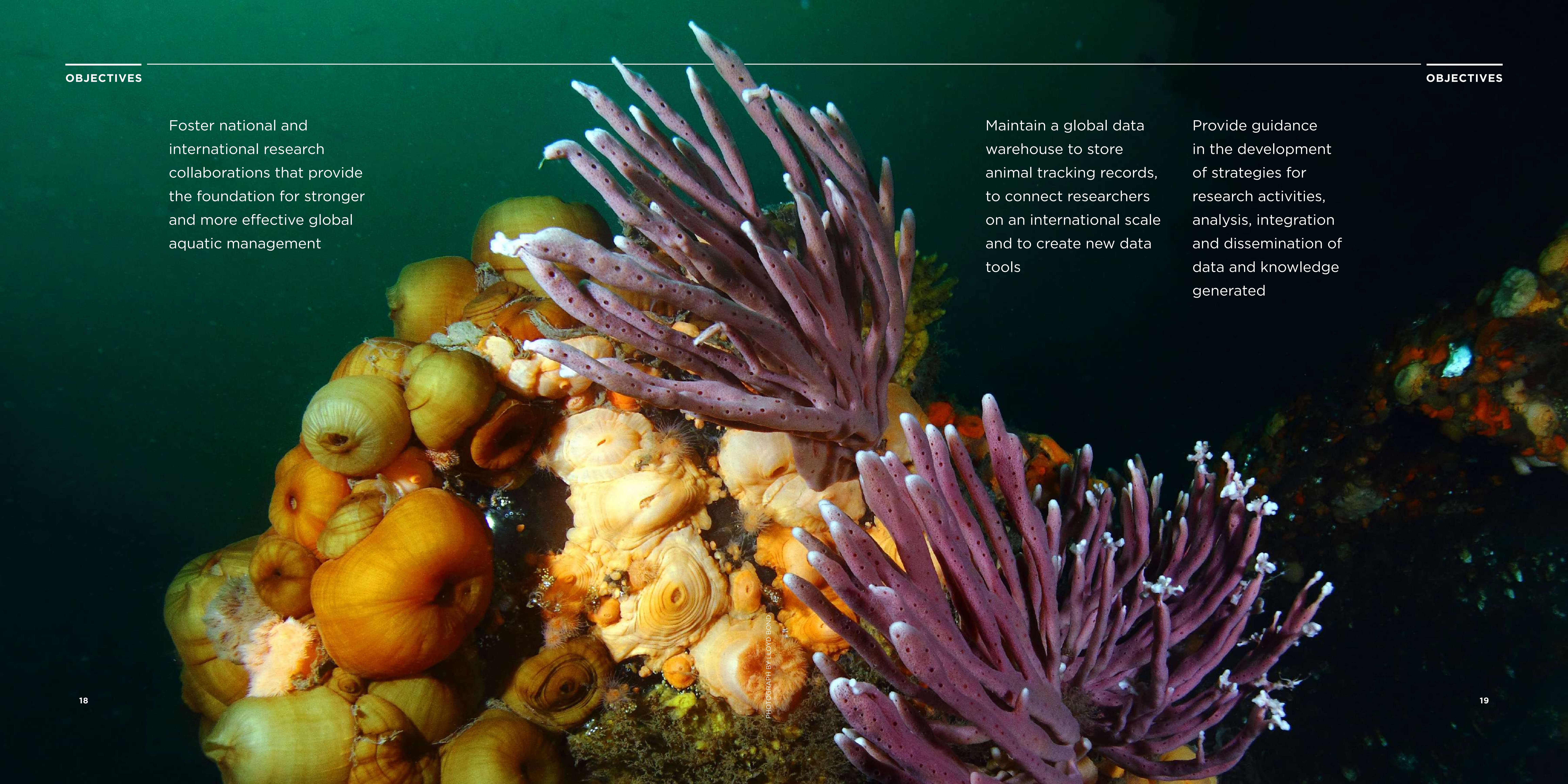
To inform the sustainable management of aquatic animals by providing knowledge on their movements, habitats and survival in the face of a changing global environment.



PHOTOGRAPH BY LLOYD BOND

OBJECTIVES

Develop and use tracking technologies to identify critical habitats and migration pathways of aquatic animals



PHOTOGRAPH BY LLOYD BOND

Foster national and international research collaborations that provide the foundation for stronger and more effective global aquatic management

Maintain a global data warehouse to store animal tracking records, to connect researchers on an international scale and to create new data tools

Provide guidance in the development of strategies for research activities, analysis, integration and dissemination of data and knowledge generated

OBJECTIVES

OTN: A FORMULA FOR INNOVATION

It's a great pleasure to present this reflection on OTN over its first 10 years. Together, we have had the opportunity to co-lead the Network since its inception and we take tremendous pride in seeing the immense progress and achievements to date.

Since 2008, OTN has been creating a unique global research, conservation and infrastructure platform that tightly integrates biological, oceanographic and social sciences; promotes technological innovation; and fosters collaborative partnerships across sectors and around the world. OTN brings to international science its unique perspective as a global biological ocean observing platform and is an important international science ambassador for Canadian diplomacy. It's a winning formula. OTN now serves more than 400 national and international researchers from more than 30 countries, has helped to train hundreds of students and is providing knowledge that's changing our understanding of the natural world to better manage the world's aquatic resources.

OTN grew out of the Census of Marine Life and a dream held by Census Chief Scientist Dr. Ron O'Dor. OTN was launched through the visionary pairing of infrastructure support from the Canada Foundation for Innovation (CFI) with research funding from the Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC).

Dalhousie University, OTN's host institution, and in particular the university's senior administration has contributed critical resources since OTN's inception to develop and foster an extremely successful model for a collaborative institutional initiative.

Industry partners such as VEMCO further strengthened OTN's platform through investments in the research and development of new technology. OTN also benefited from critical support and engagement from Fisheries and Oceans Canada (DFO), other research and government agencies, international academia, as well as Indigenous communities and working groups, organizations and members of the public. This unique formula created a nimble global science program and has enabled OTN to unlock the potential of Canada's world-class aquatic research community.

OTN is about discovery in service to people. We're proudest of OTN's commitment to, and leadership in, connecting people—from young trainees to senior researchers, and across communities, stakeholder groups, institutions and countries. This has built impactful collaborations, broken down traditional barriers in data sharing and contributed globally to the protection of our oceans.

PHOTOGRAPH COURTESY OF DALHOUSIE UNIVERSITY

These connections have been especially important in developing the rich interdisciplinary and collaborative training environment that OTN provides to students and postgraduates. OTN continues to train specialists in strategic priority areas such as interdisciplinary sciences, engineering, marine policy and conservation. Likewise, OTN has proudly helped to progress the paths of early-career researchers and faculty members by supporting their work and advancing their candidacies for national and international awards. The benefits of this are clear: we've seen our new professionals make significant achievements in interdisciplinary research methods, develop commercial spin-off companies and provide game-changing revelations about aquatic organisms that are informing critical policy and management decisions.

OTN has also built a very special culture, one dedicated to making all of our researchers succeed and where, despite the weight and responsibility of the mission, our staff and partners find joy every day in their work. This culture shined through during OTN's appearances on the Discovery Channel, the Rick Mercer Report and the Amazing Race Canada, as well as with our recent collaboration with Big Spruce Brewing to release a wildly successful beer that raised funds for ocean conservation and education initiatives.

We owe a huge debt of gratitude to our governance volunteers, especially OTN's Council and the Scientific and Data Advisory Committees for their unwavering support, service and advice; for their understanding that innovation cannot happen without risk; and for openly sharing their excitement about OTN's achievements. We especially acknowledge OTN staff members for their work and dedication—and for making it a pleasure to come to work every day.

We look forward with great confidence and anticipation to the next phases of OTN and to carrying forward the values that have made OTN a global leader in tracking, connecting and transforming ocean sciences.

Sara Iverson

DR. SARA IVERSON
Scientific Director

F. G. Whoriskey Jr.

DR. FRED WHORISKEY
Executive Director

PHOTOGRAPH BY LUTHER CAVERLY

MESSAGES FROM… SAC CHAIR

SCIENTIFIC ADVISORY COMMITTEE (SAC)

The OTN SAC advises and reports on the planning and coordination among all projects under OTN Canada. This group assists OTN in ensuring that the science undertaken in Canada aligns with the Network's international strategic direction and that OTN work in Canada addresses national priorities.

"The best thing OTN has done is serve as a platform for connecting diverse learners, scientists, knowledge holders and decision-makers. These connections have led to new ideas, papers, collaborations, learning opportunities and partnerships that have established Canada as a leader in aquatic conservation sciences."

DR. STEVEN J. COOKE

Chair of the OTN SAC

Canada Research Chair in Fish Ecology and Conservation Physiology

Director of the Institutes of Environmental Science and Integrated Science

Professor of Environmental Science and Biology, Carleton University

Department of Biology, Carleton University

ISAC CHAIR & COUNCIL CHAIR

INTERNATIONAL SCIENTIFIC ADVISORY COMMITTEE (ISAC)

The ISAC's role is to guide, advise and integrate the planning of Canadian and international research projects. This group assists in ensuring that science undertaken around the world is consistent with OTN's strategic direction and priorities.

"OTN has drawn together a global community of scientists, managers, policy- and decision- makers who are focused on the health and interconnectedness of our marine ecosystems. It has put Canada at the forefront of what is now a truly global network, integrating across the disciplines and providing a clear path for sustained ocean observing into the future."

DR. ROBERT HARCOURT

Chair of the OTN ISAC

Professor of Marine Ecology and Facility Leader, Animal Tracking, Integrated Marine Observing System (IMOS)

Department of Biological Sciences, Macquarie University, Australia

COUNCIL

The OTN Council's mandate is to provide independent, external stewardship of OTN on behalf of Dalhousie University, CFI and other OTN stakeholders. The current OTN Council is comprised of Canadian and international industry, research and policy leaders who are lending their expertise to assist in the strategic planning, management, growth and positioning of OTN.

"Empowering stakeholders is at the core of OTN's mandate. Fisheries research touches every corner of the world, creating global impact by generating regionally relevant information. OTN's ability to connect end users is unique and far reaching, a legacy of revolutionary research and collaboration that has significantly enhanced our capacity to predict and plan in the face of climate change and human influence."

DR. PETER HARRISON

Chair of the OTN Council

Professor Emeritus, School of Policy Studies, Queen's University

Former Deputy Minister of Natural Resources Canada and Fisheries and Oceans Canada (DFO)

OTN PHASE I

Phase I of OTN began with establishing the first Canadian and international tracking arrays, launching the OTN Canada research network (focused on the themes of ocean modelling, living marine resources, trophic interactions, climate variability, and ocean governance), and began to develop the first international collaborations.

OCEAN TRACKING NETWORK

2007

International Joint Venture Project award creating OTN is announced by CFI: it is the largest scientific research grant in Atlantic Canadian history, with $35M from CFI to support global monitoring infrastructure, governance and operations; $10M from NSERC to support research across Canada using OTN infrastructure; and $327K from SSHRC to support OTN social science and knowledge mobilization

2008

First OTN tracking array is established: acoustic receivers are deployed on the continental shelf off Halifax, and eventually creates the longest acoustic tracking line in the world (completed in 2012)

Inaugural meeting of OTN management and regional (Atlantic, Pacific, Arctic) research networks

OTN's data warehouse and system is launched

OTN Glider Program begins with first mission in Frobisher Bay, Nunavut

2009

Initial OTN Council and OTN SAC are formed

First international tracking array is established in Perth, Australia, nested within the Australian IMOS Animal Tracking Facility. A second OTN line is added later in Tasmania, helping IMOS create a continental-scale acoustic system

2010

Counting on Salmon Workshop is held at the Pacific Salmon Commission (U.S.–Canada), hosted by the Pacific Salmon Foundation, to review current adult salmon telemetry programs in the Fraser River system

Canadian OTN research and training network program launched (Atlantic, Pacific and Arctic)

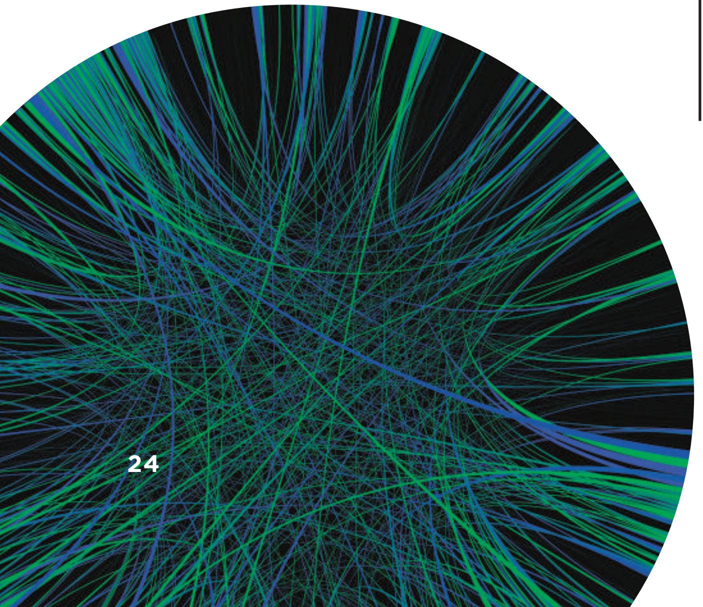
First meeting of the OTN SAC

1 ACOUSTIC TAGS are small transmitters that allow researchers to track aquatic animals underwater.

2 Larger animals can carry VEMCO MOBILE TRANSCEIVERS (VMTs), which act as both transmitters and receivers.

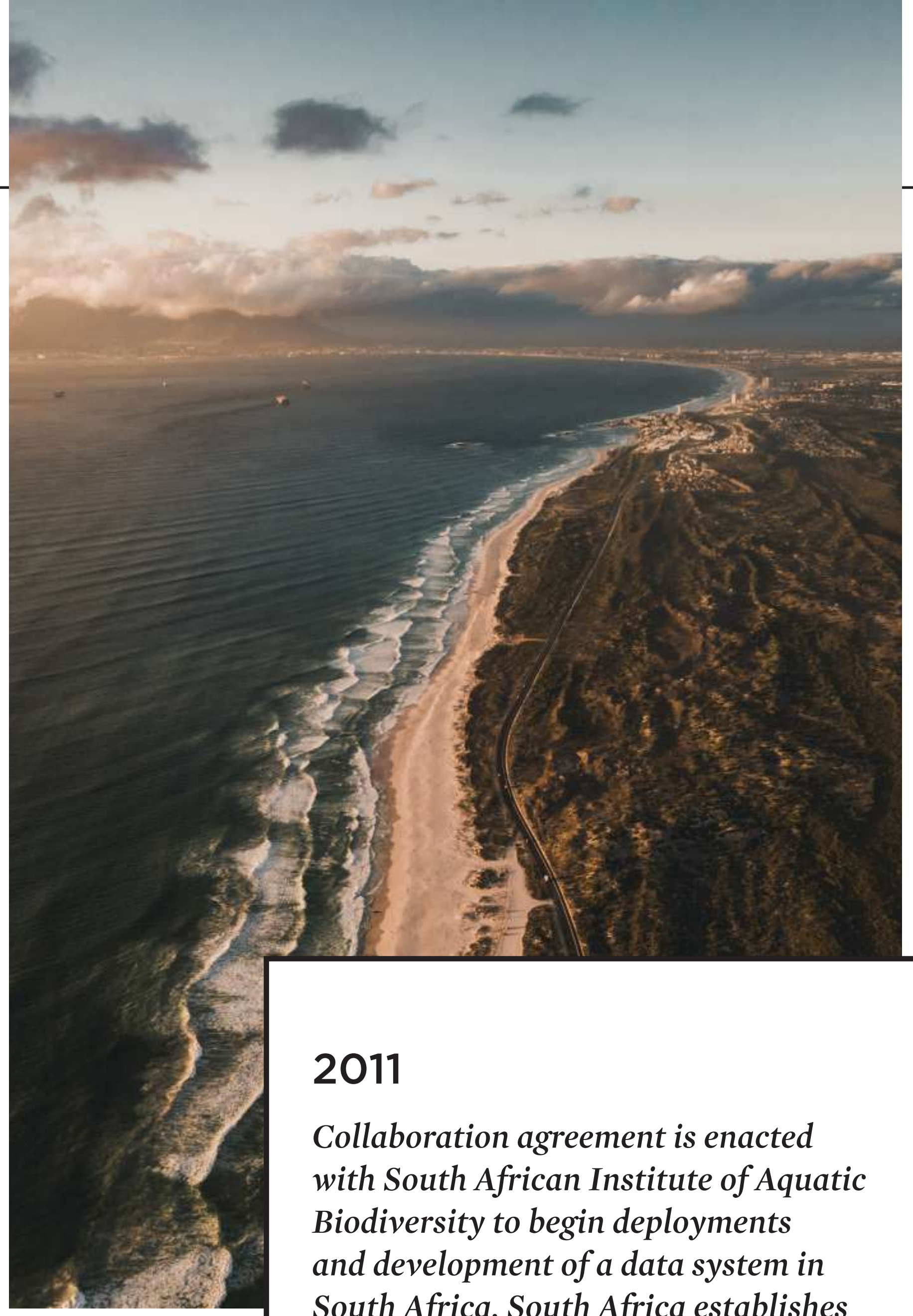
3 SLOCUM GLIDERS dive up and down collecting information underneath the waves.

4 ACOUSTIC RECEIVERS capture animal movement data.



First author connections among OTN senior scientists

PHOTOGRAPH COURTESY OF DALHOUSIE UNIVERSITY



WAVE GLIDERS float on the ocean's surface. They are emission free, propelled by wave energy and solar powered.

2011

Collaboration agreement is enacted with South African Institute of Aquatic Biodiversity to begin deployments and development of a data system in South Africa. South Africa establishes the Acoustic Tracking Array Platform (ATAP), which grows to become a telemetry hub for Africa and builds a regional data system on the OTN model (first external OTN node)

First annual OTN Canada Symposium is held at OTN headquarters in Halifax. OTN Canada project leaders and students share preliminary research designs, discuss methods and network

Cumberland Sound and Lancaster Sound Arctic receiver deployments occur, launching OTN Arctic programs

OTN Cabot Strait Line, the second-longest receiver array in the world, is installed in the Gulf of St. Lawrence

2012

OTN begins coordination with and regular attendance at the annual Great Lakes Acoustic Telemetry Observation System (GLATOS) meetings

OTN hosts special session to showcase research accomplishments ("Integrating Oceanography and Animal Tracking - the Ocean Tracking Network") at the 2012 Ocean Sciences Meeting in Salt Lake City, U.S.

German Chancellor Angela Merkel tours Dalhousie University's ocean-research initiatives, speaking with OTN Scientific Director and students

ISAC is formed to complement the Canadian SAC, and the International Data Management Committee is established in order to implement a more robust and fully integrated governance and advisory system

OTN absorbs and begins operation of three former Pacific Ocean Shelf Tracking project lines in order to support Pacific salmon research and address the recommendations of the Cohen Commission

2013

OTN helps found the international "Gliderpalooza," a grassroots, coordinated field demonstration of glider monitoring capacity (spanning Newfoundland to Georgia, U.S.)

OTN, along with international stakeholders and other experts, participates in developing the EU-Canada-U.S. Galway Research Alliance for cooperation on Atlantic Ocean research

OTN is a keynote speaker and panel member at the 1st European Research Area-Canada (ERA-Can) II Symposium on Arctic and Marine Research Infrastructure in Rome, Italy

OTN is an invited speaker and panel member at the 2nd Brazil–Canada Joint Workshop on Ocean Science and Technology in Victoria, British Columbia

OTN co-hosts a special session ("Advances in Studying Spatial Distribution") at the 2013 International Council for the Exploration of the Sea (ICES) Symposium in Reykjavik, Iceland

OTN PHASE II

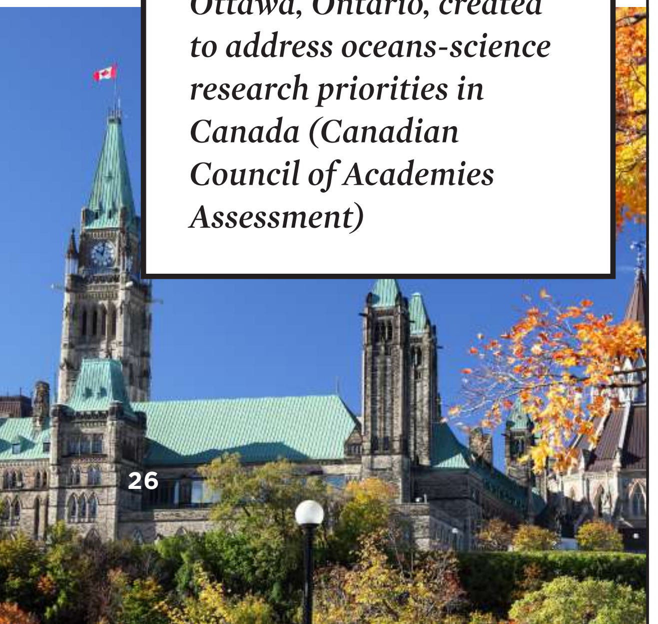
Phase II of OTN was defined by ever-increasing international collaborations and reach and by advanced integration of the scientific questions being addressed across the OTN Canada research network with that of international partners. Phase II also focused on the use of newly available technology and fostering increased capacity for training and outreach.

2014

OTN Canada begins Phase II of its NSERC-funded, pan-Canadian research and training program after successful peer reviews of past performance and future plans

OTN hosts a symposium ("The Ocean Tracking Network: Global Innovation in Technology, Science and Management") at the American Association for the Advancement of Science (AAAS) conference in Chicago, U.S.

OTN is a founding participant of the Ocean Science Roundtable in Ottawa, Ontario, created to address oceans-science research priorities in Canada (Canadian Council of Academies Assessment)



OTN is an invited speaker and panel member at the International Conference on Research Infrastructures (ICRI) ("Research Infrastructures for Global Challenges") in Athens, Greece

OTN establishes joint collaboration with Brazil to help develop and launch OTN-Brazil; helps host first aquatic tracking workshop in Rio Grande do Sul, Brazil

OTN hosts special session ("From Science to Governance: Ocean Tracking Research for the Betterment of Canadian Marine Ecosystems and Resource Management") at the Coastal Zone Canada Conference in Halifax

OTN holds parliamentary reception in Ottawa as part of the 2014 OTN Symposium

OTN hosts special session ("Big Problems, Big Networks, Big Data") at the Canadian Science Policy Conference in Halifax

The inaugural meeting to found Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG) is held. OTN supports iTAG with equipment and access to its data experts. By 2015, iTAG has deployed 1,062 receivers and tagged 2,200 aquatic animals

2015

OTN becomes the first Canadian Associated Data Unit of the UNESCO-IOC International Oceanographic Data and Information Exchange

OTN co-hosts special session ("Establishing OTN-Brazil") at the Brazilian Ichthyology Conference in Recife, Brazil; subsequently co-hosts a workshop with VEMCO on OTN tracking technology in Tamandaré, Brazil

OTN is an invited speaker and panel member at a session on "Coordination of Ocean Science in Canada" at the 2015 Canadian Meteorological and Oceanographic Society Conference in Whistler, British Columbia

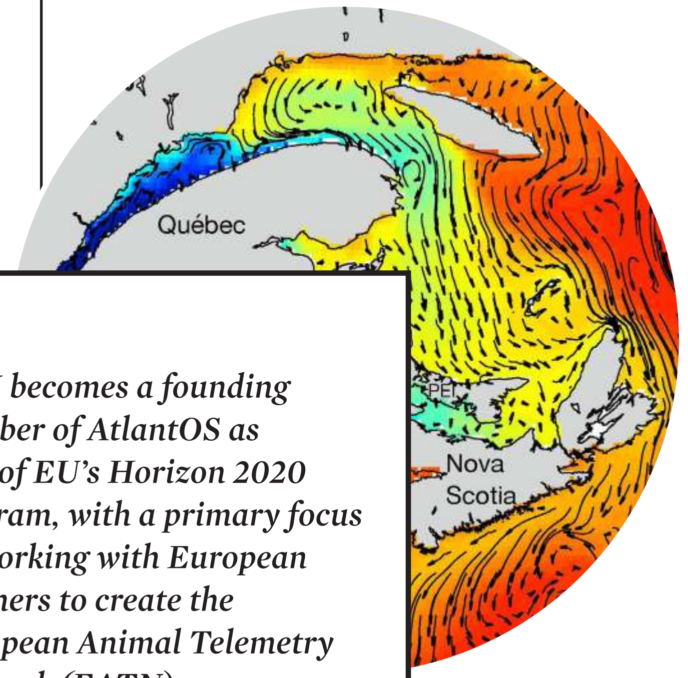
OTN's ISAC (with select trainees) publishes an invited review in *Science*, "Aquatic Animal Telemetry: A Panoramic Window into the Underwater World," and participates in several associated podcasts and media releases

OTN is an invited speaker and panel member at the forum on "Frontiers of Research on Marine Biological Science," held by the Japan Society for Promotion of Science in Washington, DC.

ideasOTN, a committee of OTN research students, is formed; it continues to generate synthesis papers and outreach initiatives

OTN is an invited speaker and panel member at the 2nd ERA-Can+ International Symposium on Arctic and Marine Infrastructure in Halifax

OTN is an invited speaker and panel member at the ERA-Can+ Roundtable on Marine and Information and Communication Technology in Lisbon, Portugal



OTN becomes a founding member of AtlantOS as part of EU's Horizon 2020 program, with a primary focus on working with European partners to create the European Animal Telemetry Network (EATN)

OTN hosts 3rd International Conference on Fish Telemetry in Halifax

OTN is an invited speaker and panel member at the working session on "Horizon 2020/ Marine and Atlantic Action Plan: Ocean Cooperation with Canada related to Ocean Observatory Science and Technologies," in Barcelona, Spain

2016

OTN becomes a founding member in the development of a Canadian Integrated Ocean Observing System

Canadian Minister of Science, the Honourable Kirsty Duncan, visits Dalhousie to tour ocean science initiatives with a separate meeting on OTN's Canadian and global operations (page 11)

OTN receives Conservation Achievement Award from the International Fisheries Section of the American Fisheries Society

OTN receives the Nature Inspiration Award from the Canadian Museum of Nature in Ottawa

PHOTOGRAPH COURTESY OF CANADIAN MUSEUM OF NATURE

OTN is an invited speaker and panel member in the session on "Expanding Partnerships across Disciplines, Sectors and World Regions" at the 3rd ICRI in Cape Town, South Africa

OTN funding is renewed, primarily through CFI and Research Nova Scotia Trust (RNST), with additional Canadian and international partnership support, and OTN becomes one of only 17 national research facilities in Canada to receive Major Science Initiative (MSI) funding, which funds OTN from 2017 to 2022 for continued operations and maintenance

OTN provides input to the Naylor Commission, Canada's Fundamental Science Review, that will structure future science network funding

OTN/Marine Environmental Observation Prediction and Response (MEOPAR) gliders incorporate passive acoustic monitors to identify baleen whales and begin exploratory missions to search for right whales in the Gulf of St. Lawrence

OTN and Big Spruce Brewing of Cape Breton, Nova Scotia, collaborate to produce the IPA-style beer Tag! You're It!; a portion of the sales helps support oceans conservation and research. The campaign raises OTN's public profile and generates more than $11K for organizations in Atlantic Canada

2017

OTN leads a coordinated monitoring mission between DFO, the University of Victoria, and Dalhousie University, using three autonomous marine gliders off the coast of British Columbia to map grey whale habitat

OTN becomes a founding member and consultant on developing the Oceans Research in Canada Alliance (ORCA)

First deployments of OTN equipment in Brazil are completed; OTN co-hosts workshop "Launching of the Data Portal and Structuring the Brazilian Ocean Tracking Network," which establishes the OTN-Brazil Telemetry Data Node, in Tamandaré, Brazil

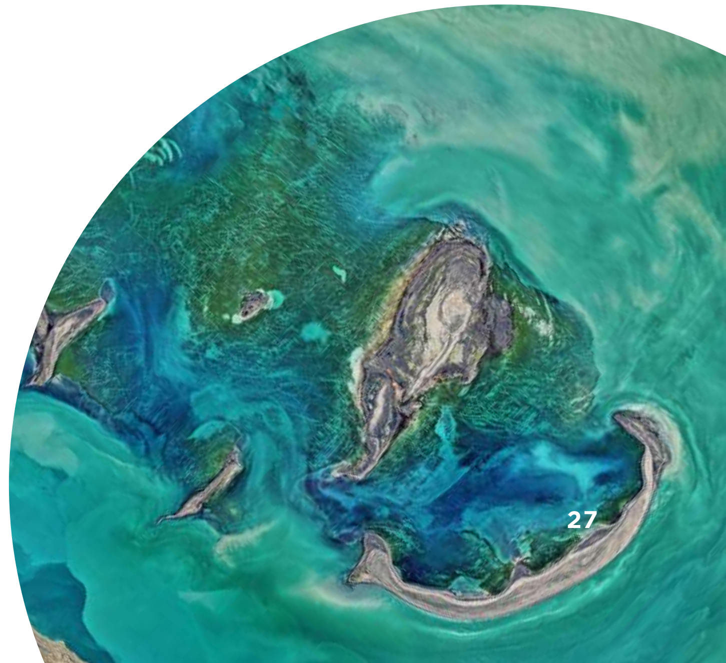
OTN expands its glider fleet under a partnered project (Memorial University and Dalhousie: Development of Autonomous Marine Observation Systems), with new funding from CFI and RNST; adds two Remotely Operated Vehicles (ROVs) and an aerial drone to its toolbox

OTN's ISAC (with select trainees) publishes comprehensive review in *BioScience*, entitled "Envisioning the Future of Aquatic Animal Tracking: Technology, Science and Application

OTN becomes a member of the EU Horizon 2020 SponGES consortium

OTN is named to the steering committee of the World Conference of Marine Biodiversity, which will convene in Montreal, Quebec in 2018

An OTN data node, developed in collaboration with and for the Florida Atlantic Coast Telemetry (FACT) array over the past three years, comes online in the Southeast Coastal Ocean Observing Regional Association (SECOORA) node of the U.S. Integrated Ocean Observing System (IOOS).



OTN has made tremendous progress in the areas of international partnerships, global receiver coverage, data collected and species tracked.

166

SPECIES TRACKED GLOBALLY

47,500

INDIVIDUALS TRACKED OVER 280 PROJECTS

1800

RECEIVERS DEPLOYED GLOBALLY

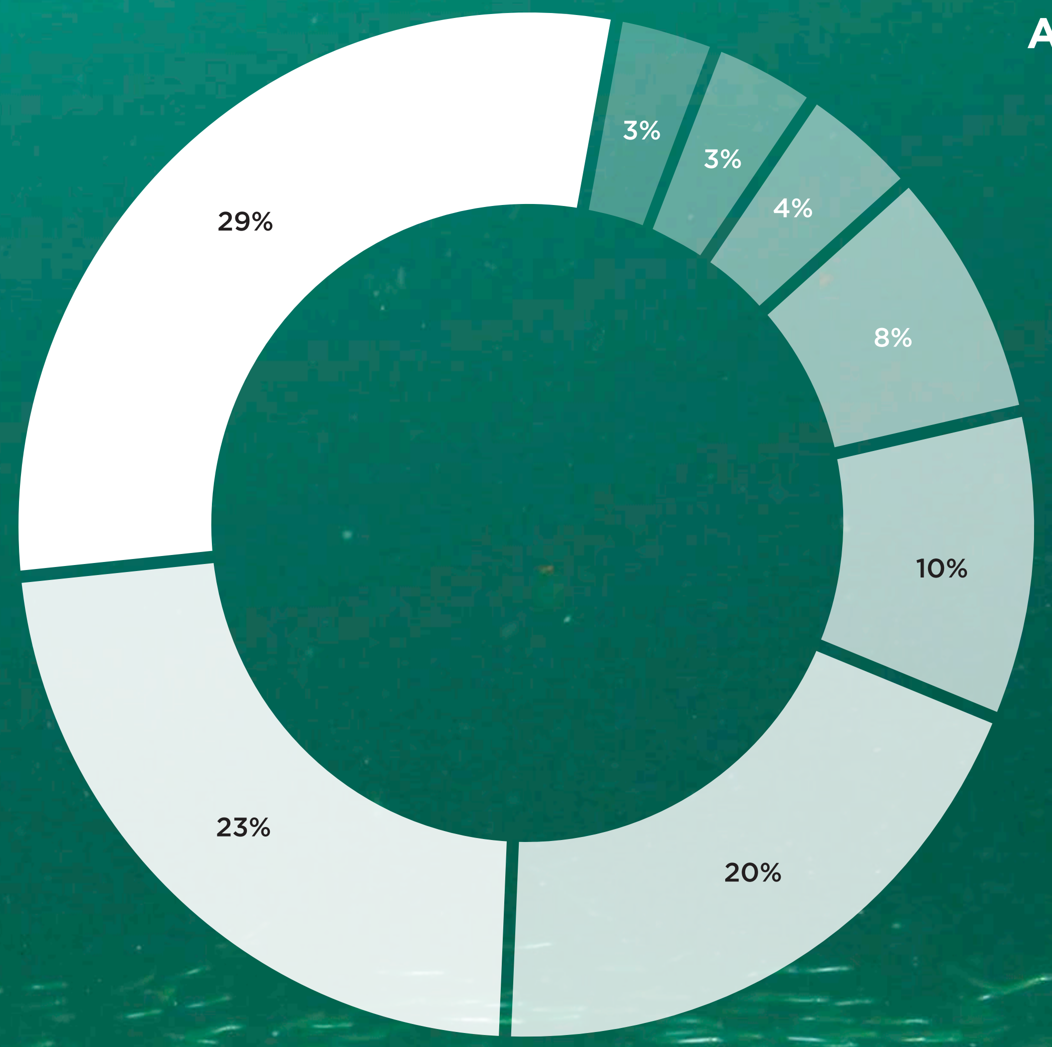
45,000

KILOMETRES COVERED BY GLIDERS

PHOTOGRAPH BY LLOYD BOND

STATS

ABOUT OUR STUDENTS (250)



- 3% EMPLOYED IN ACADEMIA (FACULTY)
- 3% HIRED BY A PARTNER
- 4% HIRED BY OTHER
- 8% HIRED BY OTHER ORGANIZATION IN USER SECTOR
- 10% HIRED BY GOVERNMENT
- 20% IN FURTHER ACADEMIC TRAINING
- 23% CONTINUING ON PRESENT CAREER/ STUDY COURSE
- 29% IN OTHER ACTIVITIES

400

SENIOR SCIENTISTS FROM 30 COUNTRIES

5

SPIN-OFF ORGANIZATIONS*

*four commercial enterprises and one ENGO

260 MILLION

ANIMAL DETECTION RECORDS COLLECTED

Kristin Boe releases a tagged brook trout as part of OTN Atlantic tracking studies.

PHOTOGRAPH COURTESY OF KRISTIN BOE

TRAINING

THE NEXT GENERATIONS OF SCIENTISTS

OTN is training new specialists in the interdisciplinary fields of ocean and aquatic sciences, marine policy and conservation. Over the past 10 years, OTN has supported over 250 students, trainees and postdoctoral fellows across Canada. In addition, more than 150 international students, technicians and professional personnel have been trained in the use and maintenance of OTN infrastructure.

ideasOTN

In 2015, Canadian OTN students and postdoctoral fellows formed a committee to improve the synthesis of collaborative research outputs. “Integrate, Describe, Expand and Synthesize OTN,” or ideasOTN, has produced more than 20 projects to help inform policy and management as well as educate the public on ocean sciences and telemetry studies.

Many OTN trainees have gone on to advanced academic study or have been hired in professional positions, including faculty, government and science outreach positions in Canada and abroad. OTN students and their research are profiled throughout this reflection on the Network’s first 10 years.

OTN researchers Kim Whoriskey and Dr. Micheal Orr tagging Atlantic salmon kelts in Middle River, CB.

PHOTOGRAPH BY XAVIER BORDELEAU

SUE L'ORSA
HOMETOWN: Smithers, BC
Glider Technician

PHOTOGRAPH COURTESY OF MEOPAR

WAVE GLIDER

OTN students and trainees come from a variety of backgrounds. In the case of the OTN/MEOPAR glider team, the majority of former co-op students, having undertaken honours or graduate studies as part of OTN, have found careers in the growing field of autonomous environmental monitoring.

How did you come to work for the OTN/MEOPAR glider team?

I started to volunteer with OTN by researching international welfare standards for fish. I also assisted their field team by servicing gear and tagging Atlantic salmon. Later, I was introduced to the glider group and the rest is history.

What do you enjoy most about gliders?

I've enjoyed learning how gliders work and how they've been designed to maximize efficiency in a marine environment. Individual parts of the gliders are quite simple, but when combined, they make an impressive exploration tool. And while the technology isn't really new, the use of it is.

With whom, and how, do you collaborate?

Gliders are part of several research initiatives: we've been working closely with DFO from the beginning, collecting data along the Halifax Line [OTN's first and longest line of acoustic receivers] as part of the DFO Atlantic Zone Monitoring Program. These data are also used by OTN researchers for ocean modelling and to provide environmental context for animal-tracking research.

In Cape Breton, we work with DFO, Emera Inc. and harvesters to track snow crab in the Cabot Strait, which are integral to local fisheries and livelihoods.

Together with the MEOPAR Whales Habitat and Listening Experiment (WHaLE), we also equip gliders with echosounders and hydrophones to identify feeding grounds and migration routes for whales, including the endangered North Atlantic right whale.

Our glider group was one of Canada's first, so we've gained a lot of experience with gliders and now work with newer groups across the country to familiarize them with the technology.

Describe the benefits of using glider technology to collect animal-movement data.

Gliders are key to providing data and environmental context for animal tracking—they can detect tagged animals, actively monitor areas where detections have been heard and observe changes in the ocean climate.

Why are gliders important tools for ocean scientists?

The benefits of research gliders are huge—they're cost effective, environmentally friendly and provide high-quality data. They can be out for 24 hours a day for months at a time, during bad weather and in areas that can be difficult to access. It's a leap where most new ocean monitoring technology is a step.

What aspects of glider work would surprise people?

Glider work is not limited to deployment and retrieval—we work with scientists to design mission objectives, plans and risk assessments. Before every mission, we collect data on currents, active fisheries in the area, vessel traffic, potential weather events and solar input. People are often surprised that we can pilot gliders from any place with an internet connection. Some missions require 24-hour-a-day piloting, but I've also piloted from a smartphone on the road while travelling across the country.

OTN researchers capture and study anadromous brown trout in the Floet watercourse, northern Norway.

PHOTOGRAPH BY XAVIER BORDELEAU

INFORMING POLICY

SUPPORTING SCIENCE-BASED MANAGEMENT

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

INTERNATIONAL MARINE PROTECTED AREAS (MPAs)

Franziska Broell, a former OTN PhD student (now postdoctoral fellow) and co-founder of Maritime bioLoggers, has been using her unique tags to conduct research on an endangered species (common skate) in the Firth of Lorn, Scotland, in collaboration with Marine Scotland Science. Data collected from elasmobranchs (shark, skate and ray species) tracked along the OTN-supported Firth array has provided direct input to the government on the status of these species within an MPA, and was critical in delivering a scientific basis for the renewal of this MPA in 2017.

CANADIAN SCIENCE ADVISORY SECRETARIAT (CSAS)

OTN researchers and their students regularly lead the development of documents that review scientific results of OTN studies. Given the volume of science generated from OTN Pacific salmon studies alone, incorporating findings into management action is a challenge for DFO managers. DFO's CSAS places researchers at the forefront of the evidence-based decision-making process by way of consultation and advice documents, which summarize OTN findings and enable better knowledge transfer and use. OTN studies have contributed to the CSAS process, providing fundamental information needed to make critical fisheries-management decisions in Canada.

OTN studies have informed the proposed renewal of an MPA in Scotland.

PHOTOGRAPH BY DOMINIK SCHRODER/UNSPLASH

POLICY

SUSTAINABLE MANAGEMENT OF EMERGING FISHERIES

In the 1960s, a small Greenland halibut fishery was developed by Inuit communities near Cumberland Sound, Nunavut, in the Canadian Arctic. A management boundary was established to divide this ice-based fishery in the northern portion of the Sound from international fishing waters in the southern, deeper portion, as it was thought that distinct populations of Greenland halibut occupied each area. However, OTN telemetry research demonstrated direct connectivity between these two populations, with fish crossing the management boundary on a seasonal basis. In a changing Arctic climate, years of poor ice coverage had pushed the community fishery further north. As a direct result of OTN research, the management line was moved to encompass the whole of Cumberland Sound, thereby making it available to the community-led fishery year round. The new plan is proving more sustainable for both the Greenland halibut population and the community.

POLICY

OTN researcher Nigel Hussey releases a tagged Greenland shark in the Canadian Arctic.

PHOTOGRAPH BY STEPHEN FIELDS

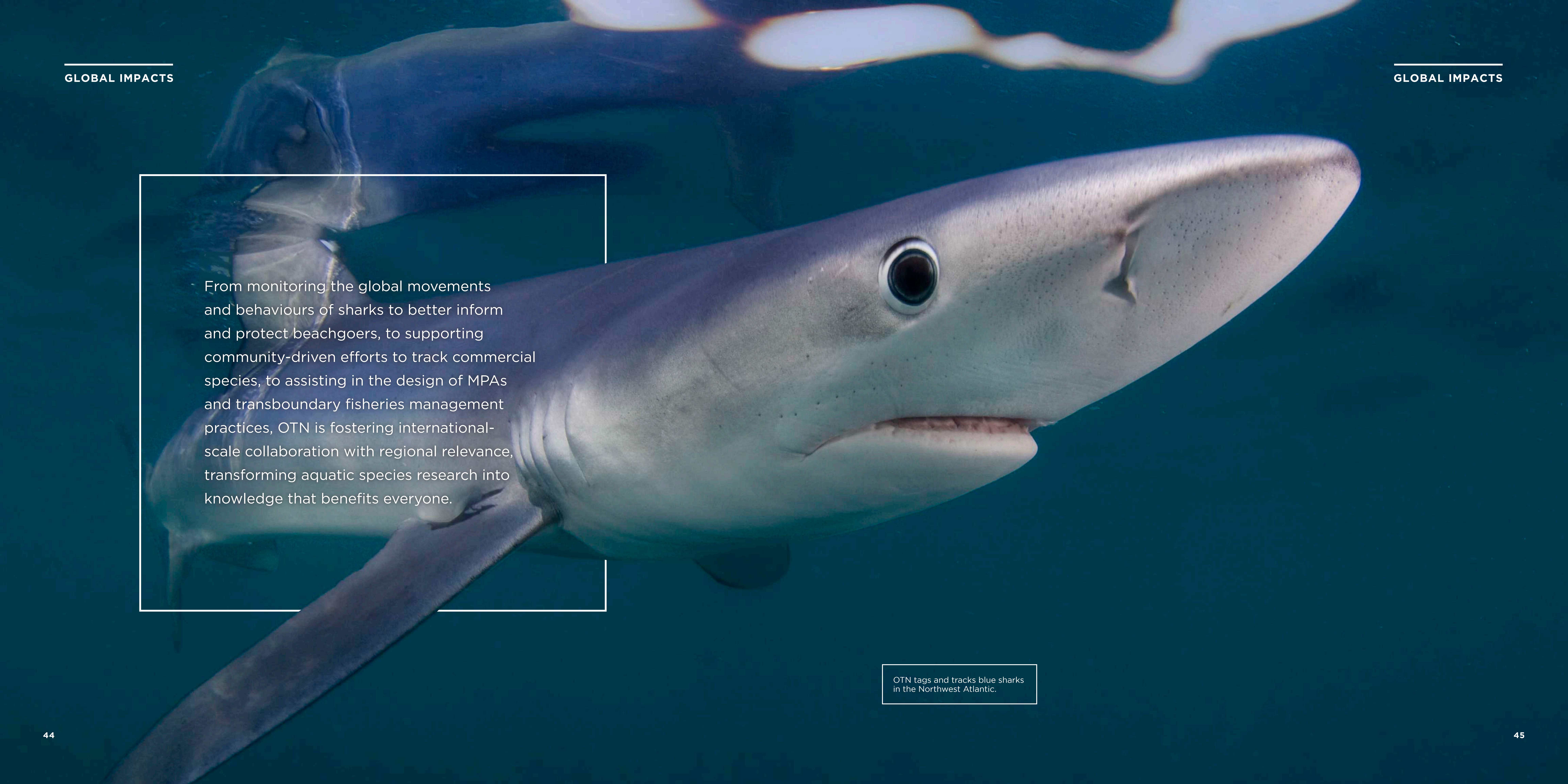
The remote Kerguelen Islands, also known as the Desolation Islands, are the site of OTN brown trout tracking studies.

PHOTOGRAPH BY XAVIER BORDELEAU

GLOBAL IMPACTS

OTN's impacts reach across Canada and around the world. Key national and international partnerships leverage resources and support integrated efforts to track critical species and ecosystem changes.

GLOBAL IMPACTS



From monitoring the global movements and behaviours of sharks to better inform and protect beachgoers, to supporting community-driven efforts to track commercial species, to assisting in the design of MPAs and transboundary fisheries management practices, OTN is fostering international-scale collaboration with regional relevance, transforming aquatic species research into knowledge that benefits everyone.

OTN tags and tracks blue sharks in the Northwest Atlantic.

AUSTRALIA & TASMANIA

PERTH, AUSTRALIA

Established in 2009 in partnership with the IMOS Animal Tracking Facility (IMOS-ATF), the OTN-Perth Line was the Network's first international acoustic array and serves researchers tracking marine animals such as whale sharks, white sharks, tuna, pink snapper and seals. The array helps monitor the movements of highly migratory tagged white sharks, especially in the vicinity of Perth beaches where the information is used to reduce human-shark interactions.

BASS STRAIT, TASMANIA

The OTN-Tasmania Line has become an important component of IMOS-ATF. The array monitors large-scale species movements, as well as the role that one of the country's major boundary currents plays in driving these movements.

The snow crab fishery in northern Cape Breton generates economic opportunities, ensures food security and supports the livelihoods of coastal communities.

PHOTOGRAPH BY NIKKI BEAUCHAMP

FLAGSHIP PROGRAMS

These highlighted projects are a few of the many operating out of the Maritime region.

BLUE SHARK

Blue sharks are the most common bycatch shark species in commercial high seas and coastal fisheries. They are a key component of the marine food web, keeping fish populations and other elements of the ocean ecosystem in balance. Since 2013, OTN has led a special study using long-life acoustic tags and satellite tags to track a population of blue sharks known to spend part of their life cycle in the Northwest Atlantic. Tagging activities have been nested within a Dalhousie University undergraduate course.

TORPEDO RAY

In 2015, OTN and Dalhousie University researchers deployed the first satellite tag on an electric ray in Ketch Harbour, Nova Scotia. Torpedo rays, the largest and most powerful of the electric rays, can deliver a 200 volt shock to stun prey and defend against predators. The deployment of electronic tags on electricity-producing creatures had not been attempted before. Once thought to be creatures of the coastline, tracks from satellite tags have documented migrations of these rays up to 1,000 kilometres offshore.

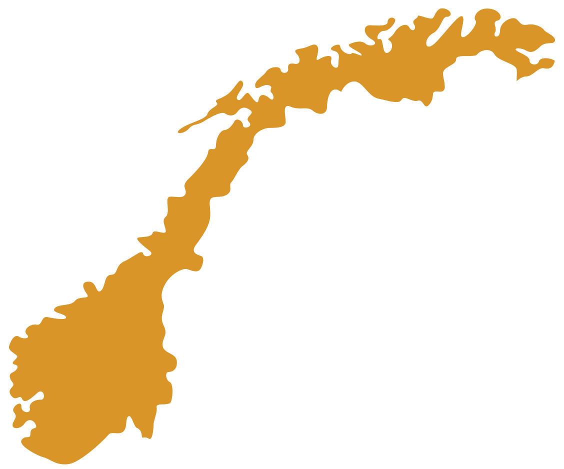
SNOW CRAB

OTN works with local harvesters, industry and government to track snow crab and answer critical questions about their movements and population structure in northern Cape Breton and the potential impacts of industrial developments in the region. Sustainable management of snow crab generates economic opportunity and supports food security for coastal communities.

The tiny Lac Bontemps research cabin under a foggy morning in the Kerguelen Islands.

PHOTOGRAPH BY XAVIER BORDELEAU

INTERNATIONAL SALMONIDS

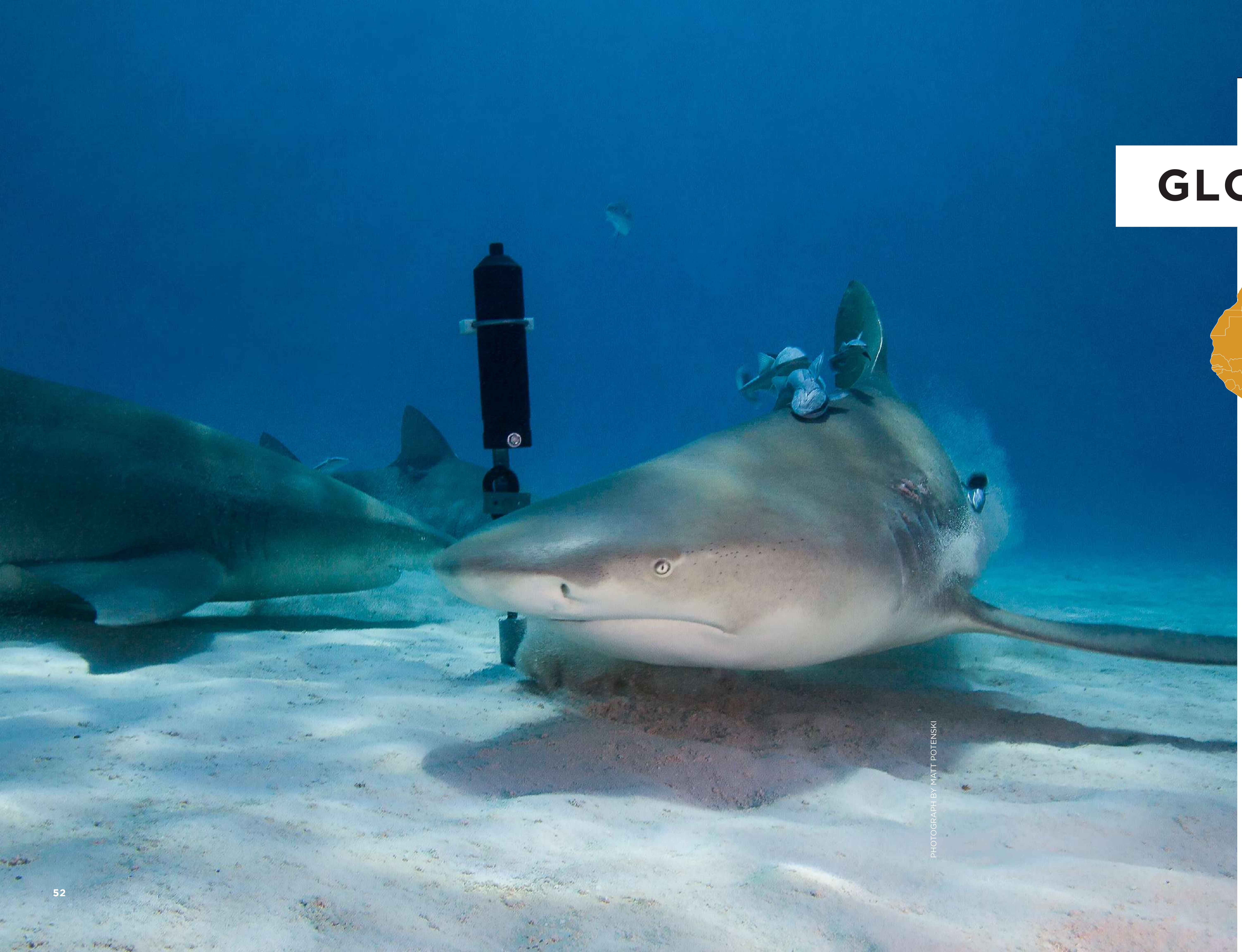


KERGUELEN ISLANDS

The French Kerguelen Islands are remote, sub-Antarctic islands situated in the middle of the triangle formed by South Africa, Australia and Antarctica. Tracking studies undertaken by OTN researchers in collaboration with French and Norwegian partners, which began in 2015, aim to understand the successful colonization of brown (sea) trout introduced to the Kerguelen Islands in the 1960s in the context of climate change and glacial retreat.

NORWAY

Sea trout numbers in central Norway have declined as much as 60 per cent over the past several decades, partly due to a decline in marine survival. Tracking studies in Norway are attempting to determine how trout use their habitat when at sea, as well as reveal the underlying causes among different marine migratory strategies. OTN Canada researchers are partnered on this study and the Kerguelen Islands study.



PHOTOGRAPH BY MATT POTENSKI

GLOBAL SHARK TRACKING

SOUTH AFRICA

In South Africa, OTN is partnered with the Acoustic Tracking Array Platform (ATAP) to track several species of highly migratory sharks—some of which have been detected as far away as Australia. The platform's array covers approximately 2,200 kilometres of coastline from False Bay, near Cape Town, to Ponta do Ouro, Mozambique. To date, the ATAP team has tagged more than 700 individual animals from 27 species.

CABO VERDE

The waters of Cabo Verde off the coast of West Africa hold one of the last remaining hotspots for sharks in the North Atlantic Ocean. Illegal trawling and shark finning threatens much of the coastal marine wildlife. Detailed scientific information is scarce in the region, preventing science-based management. OTN is involved in efforts to tag and track weasel sharks, nurse sharks, and other elasmobranchs to better understand their movements and habitat use in Cabo Verde.

MOZAMBIQUE

A volunteer expedition program, "Underwater Africa," has been partnering with OTN on a shark tracking project in Mozambique's Inhambane Estuary. The organization's focus ranges from tracking shark species to studying the effects of microplastics in the marine environment. Bull shark tracking in particular aims to provide information on shark movements and behaviour to reduce the high number of fatal shark attacks in the area.

GULF COAST COLLABORATIONS

INTEGRATED TRACKING OF AQUATIC ANIMALS IN THE GULF OF MEXICO (iTAG)

iTAG is a community of researchers working to advance marine animal tracking capabilities in the Gulf of Mexico. Utilizing OTN-supported tracking array expansion and data expertise, studies of critical reef fish abundance and residency are informing changes to commercial and recreational fishing practices in the Gulf.

FLORIDA EVERGLADES

This OTN collaboration with Florida International University is studying movements of acoustically tagged snook and tarpon in the context of increased salinity in Florida Bay and the subsequent die-off of nutrient-rich and protective seagrass beds. The research is documenting the distribution of these species across two lake systems that vary in nutrient status (one enriched, one unenriched). As the effort to return the Everglades' freshwater input to historical, pre-drainage conditions continues, these studies are addressing uncertainties regarding how salinity and other environmental changes will affect current fish communities. There are future plans to begin acoustic tracking of the endangered American crocodile.

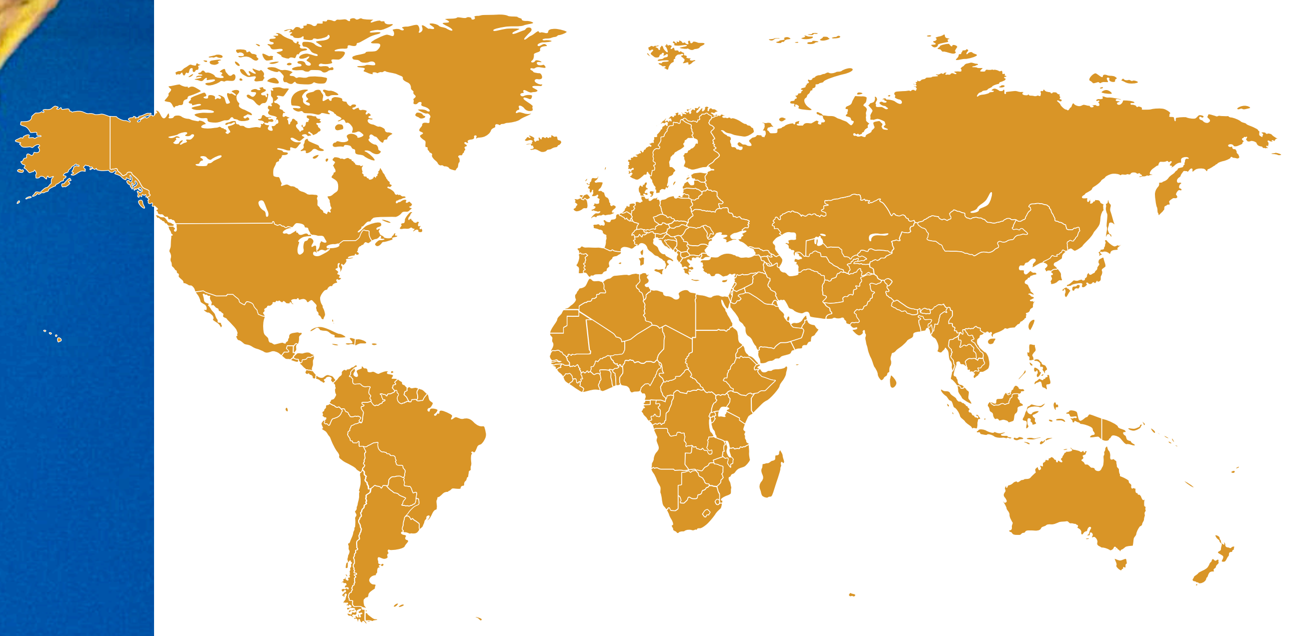
FLORIDA ATLANTIC COAST TELEMETRY (FACT)

The FACT array is a regionally coordinated effort between more than two dozen marine research organizations. It is using acoustic telemetry to reveal the behavior of fishes and sea turtles in the South Atlantic, Bahamas and the Caribbean Sea. In 2016, OTN data managers helped FACT establish an OTN data node structure, which creates a virtual "lost and found" of animal tag IDs. These collaborations are knitting OTN assets together with those in the U.S. to establish a continental-scale system of acoustic arrays for North America.

BOOs capture the movements of highly migratory pelagic animals far offshore.

PHOTOGRAPH BY MASAKAZU USHIODA/SEAPICS.COM

OCEANS OF OPPORTUNITY



BOO PIRATA

Deep-sea buoys help monitor global weather patterns and ocean currents. When equipped with acoustic receivers, these offshore, interoceanic buoys have the potential to capture movements of highly migratory animals in areas that would not otherwise permit receiver deployments. For this reason, they are termed “Buoys Of Opportunity” (BOO). Deployments on the Prediction and Research Mooring Array in the Tropical Atlantic (PIRATA buoy array), among other collaborations, have positioned OTN as a contributor to the Horizon 2020 AtlantOS project, a pan-Atlantic Ocean observing initiative.

BOO DAVIS STRAIT

A BOO deployment has also been set up in the Davis Strait, which lies between Baffin Island and Greenland and connects the North Atlantic Ocean to the eastern Arctic Ocean. This array supports both OTN Arctic studies and those of international collaborators tracking Greenland halibut, Greenland shark, Arctic skate, Arctic cod, narwhal and Atlantic salmon.

OTN DATA CENTRE

OTN researchers collaborate not only by virtue of proximity and the cross-pollination of their target species and study areas, but also through the development of methods and tools for data synthesis, analysis and visualization. OTN's data warehouse is connecting a global community of researchers, as well as providing open source tools and contributing to global data standards.

PHOTOGRAPH COURTESY OF DALHOUSIE UNIVERSITY

LENORE BAJONA

HOMETOWN: Halifax, NS
Director of Data Management

What is the OTN Data Centre?

The OTN Data Centre provides open-source tools for data curation and the management, visualization and analysis of telemetry data. We assist in the implementation of internationally standardized data nodes and promote international data exchange. One of our key goals is to improve and automate tracking by processing, loading and distributing animal tracking data to our collaborators and the public.

Describe OTN's involvement on international data bodies and the importance of having a voice as an international data platform.

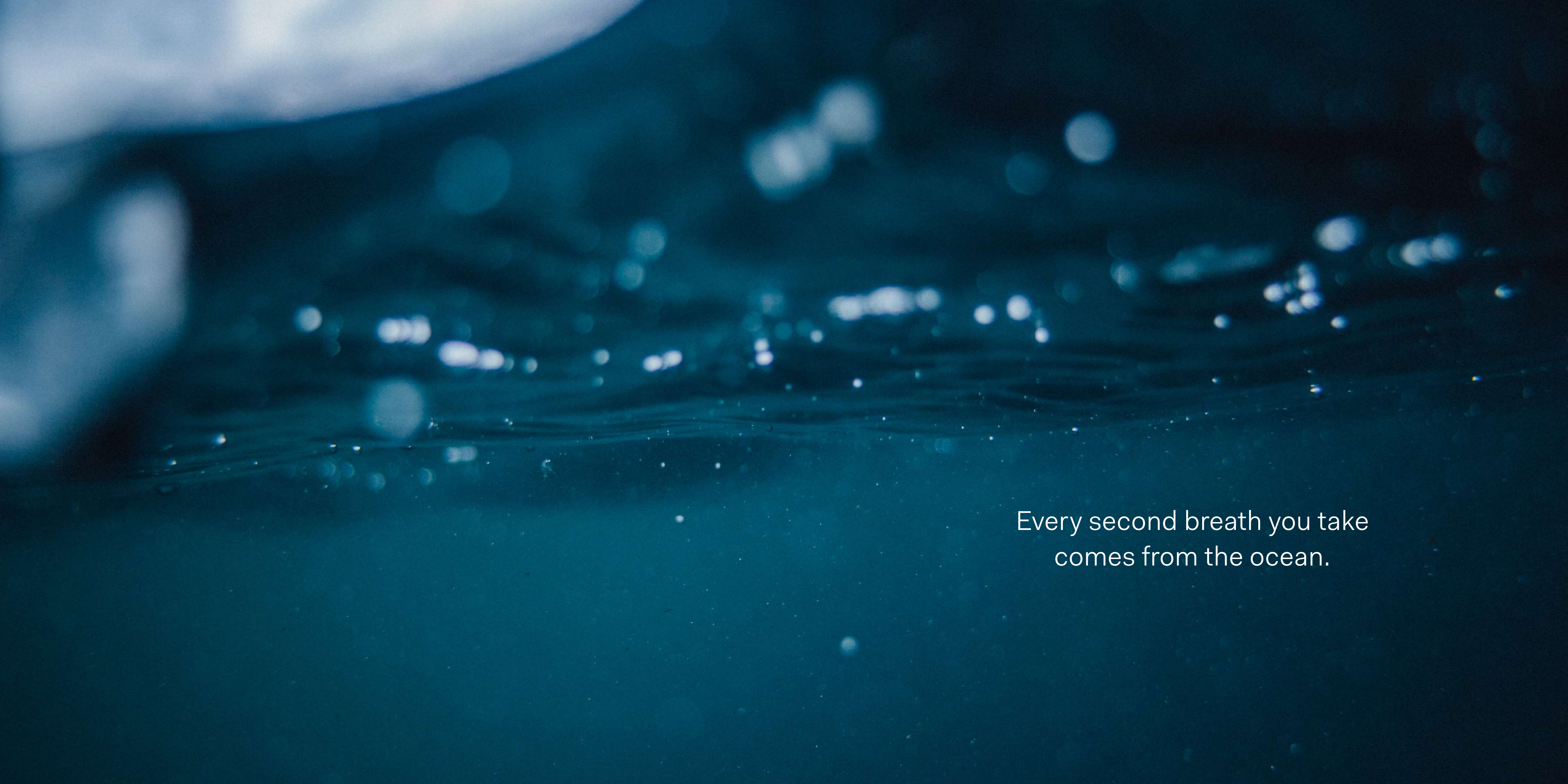
OTN is one of only a few aquatic animal telemetry data systems and the only one with a global reach. It is the longest running and has the largest collection with regards to geographic and taxonomic coverage. In 2015, based on its merits and sophistication, OTN was accepted as the first Canadian Associate Data Unit (ADU) of the International Oceanographic Data and Information Exchange (IODE) under the Intergovernmental Ocean Commission (IOC). As an ADU, OTN is recognized as having established a data system with a global reach that meets IODE data standards and can contribute to global data-sharing standards and best practices.

How has the OTN data team transformed tracking data over the years?

We train local data managers around the world on using OTN tools for data processing, quality control and storage, and provide OTN-affiliated researchers with the most complete detection dataset possible for their tagged animals. We're helping groups like GLATOS build open-source statistical computing tools for telemetry data analysis and visualization. The OTN Data Centre's ongoing partnership with the Ocean Biogeographic Information System (OBIS) ensures that data collected from telemetry projects enter the public sphere in formats that are complete and useful to the broader international community.

Describe the benefits of integrated data networks and globally connected data nodes.

OTN has been providing assistance to other international systems and has begun the distribution of "regional" nodes to better reconcile tracking data among geographically disparate users—for example, a tuna tagged in the Northwest Atlantic Ocean may be detected on a receiver in the Gulf of Mexico, where the tag code is a mystery. These "mystery detections" are easily identified by the tuna taggers via OTN's interconnected nodes.



Every second breath you take
comes from the ocean.

TRACKING OCEANS.

CONNECTING PEOPLE.

TRANSFORMING KNOWLEDGE.

PHOTOGRAPH BY STÉPHANE KIRCHHOFF

A colony of king penguins in the Kerguelen Islands, where OTN and partners are tagging and tracking brown trout.

PHOTOGRAPH BY XAVIER BORDELEAU

Tracking global environmental conditions, the movements of aquatic animals, the growth of the Network, members of the Network and their successes

TRACK

An Atlantic wolffish photographed in the waters around Nova Scotia.
PHOTOGRAPH BY LLOYD BOND

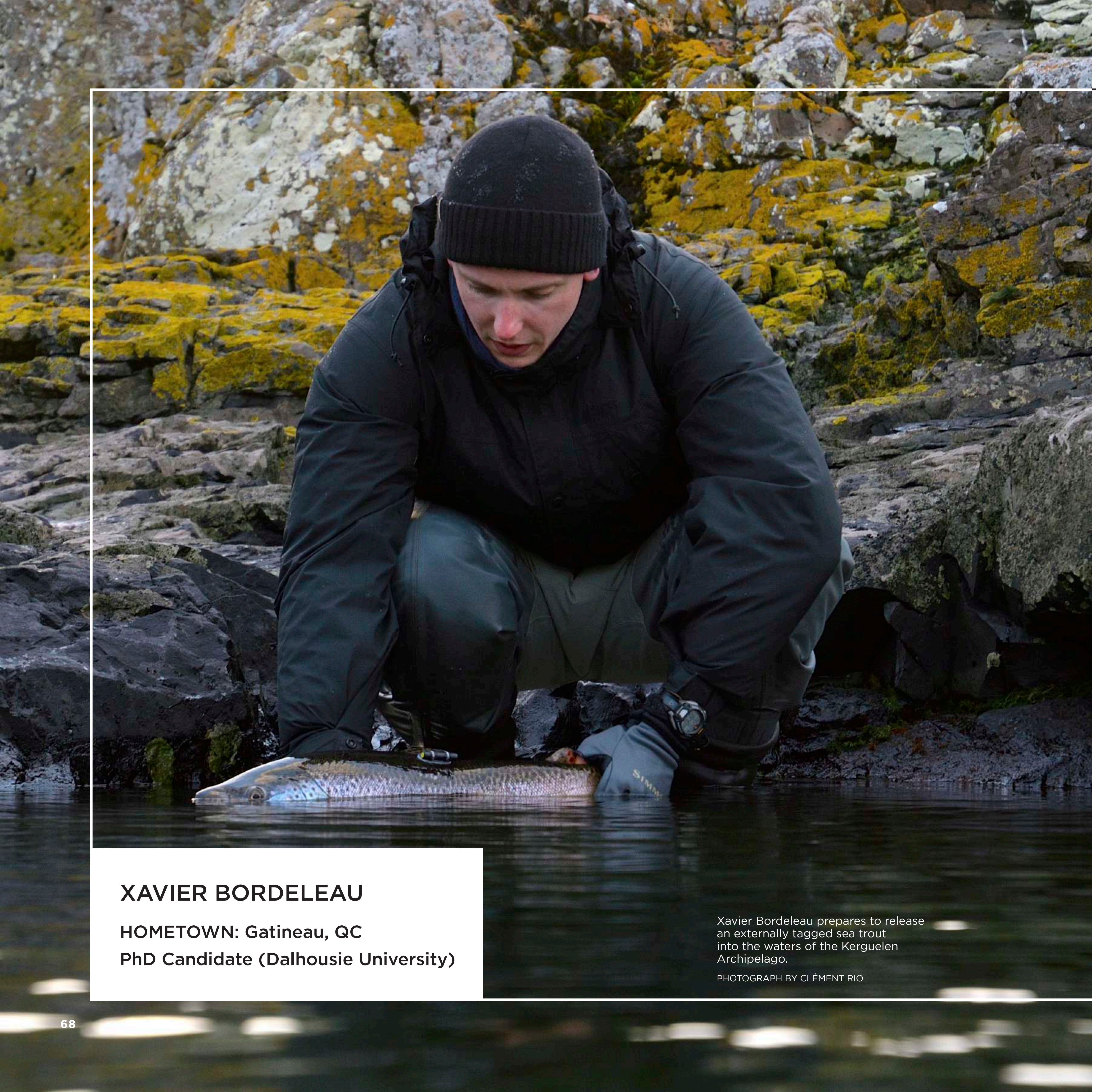
MODELLING THE BIG BLUE

BEYOND ANIMAL TRACKING

Picturing the future of vast and dynamic oceans is challenging. Examining the environmental conditions that animals encounter is a critical aspect of understanding what drives their movements and survival and, in turn, helps us manage our use of the oceans for a sustainable future.

TODAY'S INFORMATION, TOMORROW'S OCEAN

Modelling helps us see into the future. Experts can answer big questions about changes in our underwater world by tracking oxygen decline, plankton biomass, temperature and shifting sea ice in relation to animal movements. We're not just tracking animals—we're tracking oceans.



XAVIER BORDELEAU

HOMETOWN: Gatineau, QC

PhD Candidate (Dalhousie University)

Xavier Bordeleau prepares to release an externally tagged sea trout into the waters of the Kerguelen Archipelago.

PHOTOGRAPH BY CLÉMENT RIO

LIVES OF ATLANTIC SALMON

Atlantic salmon have been a large focus of OTN research due to their ecological, cultural and socioeconomic importance. A network of tracking stations in the Cape Breton Bras d'Or Lake Biosphere Reserve is assessing mortality and survival strategies along migratory journeys and across tremendous spatial scales.

A salmon kelt ready for release after being tagged in Cape Breton's Middle River.

PHOTOGRAPH BY LEAH STROPLE

What has telemetry taught you about salmon movements in the Bras d'Or Lakes?

Our findings suggest that following spawning in late fall, salmon in poor condition with depleted energy reserves either died or left the river shortly thereafter, while salmon in better condition spent the entire winter in the river before migrating out to sea in the spring. It seems that this decision about when to leave the river may have a large influence on their longer-term survival.

What's been the most surprising discovery?

Atlantic salmon are remarkable animals, often undertaking indirect, long-distance migrations to the coasts of Greenland to feed, and subsequently returning to spawn in the exact river in which they were born.

Why are Atlantic salmon important?

Atlantic salmon are very important ecologically, culturally and economically, but are declining throughout their global range, largely because of people. Here in Nova Scotia, most Atlantic salmon populations are now endangered and I feel that we have the responsibility to care for and protect them. This starts with gaining scientific knowledge on the factors contributing to mortality, especially at sea. What's happening to salmon in the marine environment has largely remained a mystery.

What is the legacy of this research?

Our research has led to a better understanding of some of the factors contributing to differences in the mortality and habitat use of Atlantic salmon in the Bras d'Or Lakes after they spawn. We have also documented some of the consequences associated with current management practices on post-spawners, which has led to new questions about how these practices could be improved to minimize their impact on repeat-spawning rates, as well as on the role that repeat spawners play in population maintenance.

An American eel slithers into an open spot in an underwater meadow of estuarine eel grass.
PHOTOGRAPH BY SEAN LANDSMAN

MYSTERIOUS MIGRATIONS OF AMERICAN EELS

Bordered by four ocean currents and unbounded by land, the Sargasso Sea in the North Atlantic Ocean is where the story of the American eel begins—and, if they're lucky, ends.

One of North America's most endangered fish, eels migrate thousands of kilometres to protective inland waters along North America's eastern seaboard and mature for 10 to 25 years before beginning a perilous migration back to the Sargasso Sea, where adults die after spawning a new generation. Prior to OTN studies, over a century of research had failed to document the journey of American eels; electronic tags recorded the first formal observations of eels entering the Sargasso Sea, and revealed a two-phase migration. This is an important step in understanding routes and migration cues, which will help with conservation planning for this species.

SEAL SCIENTISTS

A grey seal outfitted with tracking tags rests on the beaches of Sable Island.

PHOTOGRAPH BY DAMIAN LIDGARD

Located 300 kilometres southeast of Halifax, surrounded by the mighty waters of the North Atlantic, lies a crescent-shaped sandbar called Sable Island. A sliver of iconic Canadian landscape, the island teems year-round with birds, wild horses and the world's largest breeding colony of grey seals.

NOVEL TAGS, NOVEL DATA

OTN researchers outfitted grey seals with innovative tracking tags that enhance ocean monitoring by going where humans and robots can't. Tags tracked the seals, but also collected oceanographic data and recorded interactions between seals and other tagged animals. These unwitting seal scientists revealed ocean "hotspots," areas of high productivity or importance, which determine biodiversity in the Northwest Atlantic and Gulf of St. Lawrence.

PACIFIC SALMON: SURVIVING THE JOURNEY

PHOTOGRAPH BY SCOTT HINCH

The longest river in British Columbia, the Fraser River flows almost 1,500 kilometres from the Rocky Mountains, through Vancouver's bustling port and into the open ocean. The multitude of waterways that feed into the Fraser River are among the most ecologically rich in the world and are a nursery for Pacific salmon populations. Recently, survival of salmon at sea has changed for the worse.

More than 2,500 sockeye salmon, at all life stages, were tagged in a seven-year OTN study to capture information on their movements and survival. Documenting the movements of juvenile salmon, especially as they prepare to transition to life in saltwater, is crucial due to the high mortality they experience and what role this mortality plays in subsequent generations.

PHOTOGRAPH BY STEPHEN FIELDS

CONNECT

Connecting infrastructure, communities, resources, researchers, policy-makers, industry, and other stakeholders at local and global scales

A Liquid Robotics Wave Glider is successfully recovered in Halifax Harbour.

PHOTOGRAPH BY NIKKI BEAUCHAMP

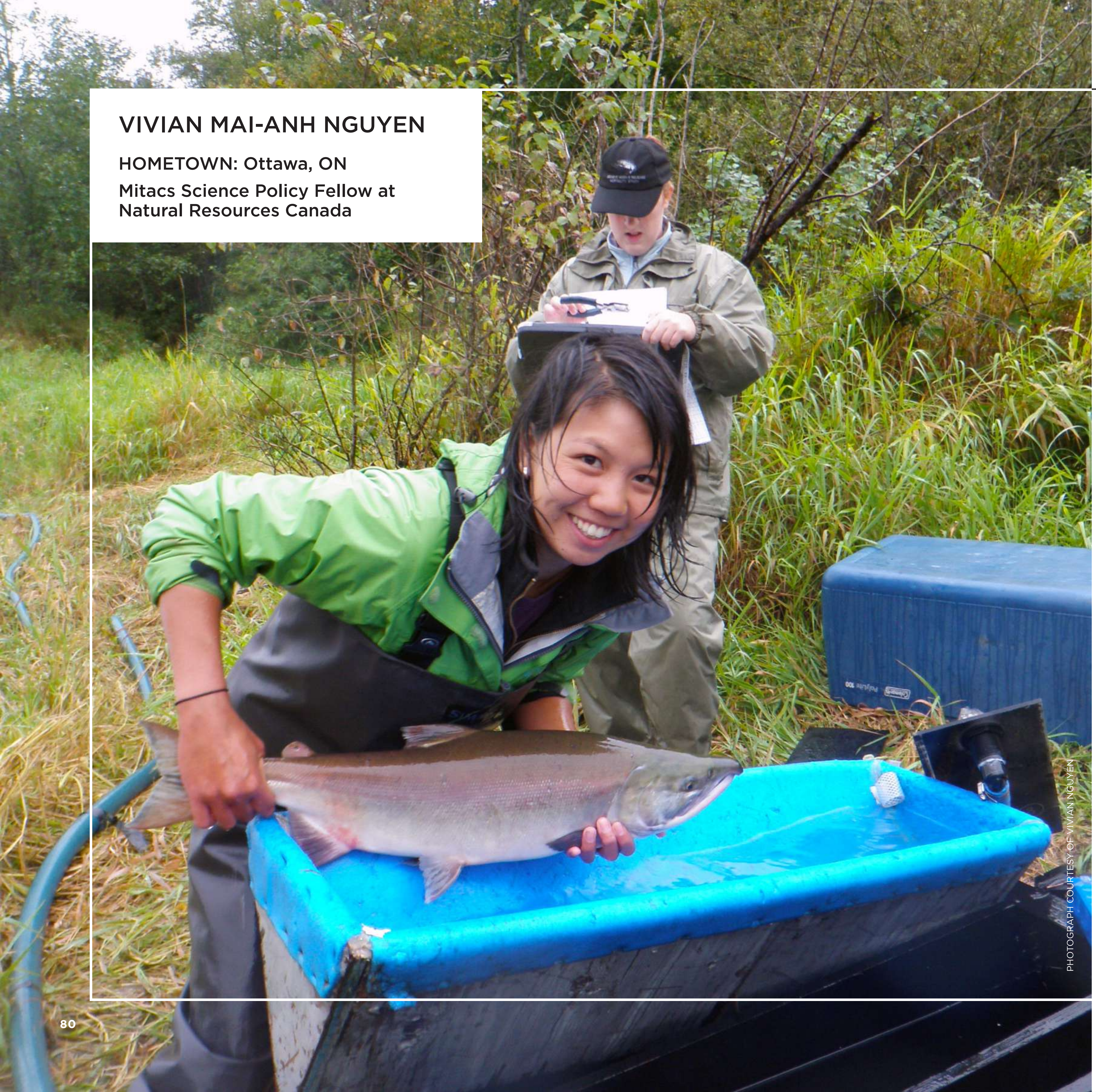
ROBOPROBES

OCEANS OF THE FUTURE

Once a proof of concept, gliders (marine autonomous vehicles) are now a safe, energy-efficient and standard tool for revealing life underwater. Slocum Gliders (electrically powered) and Wave Gliders (solar and wave powered) can travel thousands of kilometres for months at a time while collecting data on marine animals and ocean ecosystems.

FROM LITTLE TO BIG

In partnership with the Canadian Wildlife Federation and MEOPAR (WHaLE), hydrophone-equipped gliders are listening for the calls of large baleen whales across the Scotian Shelf and the Gulf of St. Lawrence. Understanding the migration routes and habitat use of Canada's great whales will help reduce accidental ship strikes and fishing-gear entanglements—the main causes of death for these slow-moving leviathans. Glider data is providing researchers with the scientific basis to establish policy and protected habitats for Canada's whales.



VIVIAN MAI-ANH NGUYEN

HOMETOWN: Ottawa, ON

Mitacs Science Policy Fellow at Natural Resources Canada

PHOTOGRAPH COURTESY OF VIVIAN NGUYEN

FROM SCIENCE TO SOCIETY

Interest in new scientific findings, particularly from telemetry, is high among regulators. However, research suggests there are barriers to the adoption and implementation of these findings. The OTN social-science component investigates potential avenues for translating new scientific knowledge into real-world fisheries policy and management strategies.

What role does social science play in natural science studies?

Human behaviour and activities often drive changes, both negative and positive, in the natural environment, so understanding the human side of the equation is extremely important in influencing positive impact.

How is science embodied in fisheries management and how does OTN fit into science aimed at management applications?

Science should underpin most fisheries management strategies and practices; however, new knowledge is generated every day, and new tools are developed to conduct more accurate and precise research. OTN connects projects and multidisciplinary studies, which is helpful in painting a broader picture for management applications. This is important, especially when fisheries managers work with different scales and management zones.

What have been the results of your study on the social science of acoustic tracking?

An analysis of almost 200 fish telemetry case studies identified that researchers who collaborate broadly and engage with stakeholders through outreach have experienced more successes in the uptake of their study findings. Therefore investments in relationship-building, growing your professional network and collaborations are key to making an impact with telemetry research.

How did OTN prepare you for your postdoctoral fellowship at MITACS?

OTN enabled me to explore the social science aspects of telemetry research and, in turn, develop expertise on how to integrate science into fisheries policy and practices.

Jack (Meyok) Omilgoetuk releases tagged Arctic char back into Ferguson Lake, Nunavut, as part of OTN Arctic studies.

PHOTOGRAPH BY JEAN-SÉBASTIEN MOORE

CONNECTING SPECIES, HABITATS AND PEOPLE

SALMONIDS IN THE SPECIES TRANSITION ZONE

Arctic char and Atlantic salmon are integral to subsistence livelihoods in Newfoundland and Labrador and Canada's remote Arctic communities. Historically, Atlantic salmon and Arctic char have split Arctic marine habitats between them, with char dominating more northerly waters and salmon taking over in the south. There is, however, a transition zone in which both species can be found living together in the same rivers. Now, warming Arctic and Atlantic climates are changing the distribution of salmon and displacing char from some of its former habitat. OTN scientists have been tracking both species' migration and residency near this zone, and monitoring environmental conditions to understand how a changing climate will shift species distribution.

Acadia University student Laura Logan-Chesney offloads an acoustic receiver as part of OTN sturgeon studies in the Bay of Fundy, Nova Scotia.

PHOTOGRAPH BY COLIN BUHARIWALLA

A 'TAIL' OF TWO STURGEON

TRIASSIC FISH IN A MODERN WORLD

Sturgeons' origins date back 200 million years, making them some of the oldest species on Earth. Their unique characteristics have remained relatively unchanged since the earliest fossil records. Despite their long-established presence, new threats are emerging: large, late-maturing sturgeon must run a gauntlet of challenges, including rapidly changing aquatic environments and human activities, if they are to survive to reproductive age.

OTN Atlantic sturgeon studies connect fish movements, behaviour and habitat use to potential overlap in tidal energy developments and commercial fisheries in the Bay of Fundy region. A parallel study on Canada's west coast in the Fraser River is generating baseline movement data on Pacific white sturgeon, and investigating the impacts of angling stress from sport fishing on these animals' survival after release.

OTN studies of Greenland shark, Arctic cod, Arctic sculpin, and ringed seal, as well as an associated oceanographic sampling program, are among the most extensive ever conducted in the Canadian Arctic. Essential data, including fish and food web interactions and oceanographic variability, is helping predict the impacts of climate change in delicate Arctic marine ecosystems.

ARCTIC INTERACTIONS

PHOTOGRAPH BY KATRIINA O'KANE

STEVE KESSEL

HOMETOWN: London, England

Director of Marine Research, Shedd Aquarium

How is the Arctic ecosystem connected to the communities that call it home? What does your OTN research mean for local communities and Arctic ecosystem health?

The majority of energy flow between upper and lower levels of the Arctic marine ecosystem is connected by Arctic cod. Local communities rely on subsistence hunting for food security. All marine species, especially seals, targeted by Inuit communities are upper-level predators, dependent on Arctic cod for a large part of their diet. OTN data can be combined with traditional ecological knowledge to help local communities more efficiently obtain and manage food resources.

What was your project's connection to the communities in which the research was conducted?

Nunavut's Resolute Bay Hunters and Trappers Association connected us with local hunters and fish harvesters who directly assisted with our research and provided crucial guidance using traditional ecological knowledge. They also helped us organize town meetings to facilitate input from the broader community and share our results with the residents of Resolute Bay.

What did you learn about the species you were tracking?

The greatest focus of our research in Resolute Bay was Arctic cod, the most important prey fish in the Arctic marine ecosystem. We learned that Arctic cod could be split into two groups based on body size, and these two groups enter and exit en masse, with timing driven by ice formation. Their distribution and behaviour was also influenced by shipping activity, which is rapidly increasing in the high Arctic as ice cover decreases over time. Through the extensive OTN receiver network established in the Arctic region, we documented the first large-scale movements of Arctic cod, which had been speculated to occur for many years but were previously unproven.

What is your most memorable experience working in the Arctic?

I would have to say it was pulling up the first shallow water Greenland shark longline in 2012. [OTN researcher] Nigel Hussey and I had a hunch that Greenland sharks would be present in the shallow waters outside of the bay. We set the line, but the weather took a sudden turn. As we pulled the line, we saw two large grey shapes emerge from the murky waters. There was not one, but two Greenland sharks on the line. This was my first time seeing a Greenland shark, and it led to us tagging many more Greenland sharks in following years as part of OTN Arctic studies.

How does this research impact the future of fisheries management?

The Arctic is the region of the globe experiencing the most rapid shifts in climate. There's an urgent demand for baseline data on marine ecosystems against which to assess future change. The OTN Lancaster Sound component has provided new insights into the biology and ecology of the most important Arctic prey fish and has provided knowledge from which to assess changing Arctic marine ecosystem dynamics.

Life in the field. OTN Arctic researchers at a study site on the shores of Resolute Bay.
PHOTOGRAPH BY KATRIINA O'KANE

An Atlantic salmon captured in preparation for tagging.
PHOTOGRAPH BY LEAH STROPLE

CATCH-22

More than two million lakes and rivers flow through pristine Canadian wilderness and provide bountiful outdoor opportunities, including one of the country's most popular activities—recreational fishing. However, catch-and-release angling doesn't always yield the best outcome for the fish.

Conservation physiology is a rapidly emerging field, which connects the biological systems of animals to underlying causes of survival and mortality. Researchers examined the fate of three popular sport fish—Arctic char, Atlantic salmon and coho salmon—that sometimes experience lethal amounts of stress after release. Researchers shared the latest information with sport fishers, who are key stakeholders and often at the heart of conservation. A major outcome of this study was the recommended handling practice of "10 seconds tops," which refers to the maximum time a fish can be held out of water for de-hooking and photography before release.

JOANNA MILLS FLEMMING

HOMETOWN: Bristol, England

Professor, Department of Mathematics and Statistics, Dalhousie University

Former Chair, National Sciences and Engineering Research Council Mathematics and Statistics Evaluation Group

PHOTOGRAPH COURTESY OF DALHOUSIE UNIVERSITY

DATA MODELLING & VISUALIZATION

Statistical modelling underpins many marine research studies, particularly in the context of linking animal movements and environmental features, which are not always documented in tandem. Researchers have benefited from advanced statistical and modelling knowledge through workshops and templates made available through the OTN modelling group.

What attracted you to environmental statistics?

I've always found statistics interesting and applying statistics and modelling to an array of scientific problems is what keeps me engaged. The late Dr. Ransom Myers, world-renowned marine biologist, first piqued my interest in marine ecology problems and environmental statistics. His passion for understanding and protecting the ocean was contagious.

What's it like to be a prominent member of the research community in a historically male dominated field?

I'm very proud. I've always been well-supported by my colleagues, and every day I see the great value that women bring to this discipline. I try my best to connect with and mentor young women wherever possible, and have myself benefited from the leadership of other women in the fields of science and research.

What meaningful contributions has statistics made to environmental science?

We've developed novel models for analyzing tracking data, as well as efficient methods for fitting these models to OTN data streams. By incorporating vast amounts of environmental information into our models, we've been able to predict animal behaviour and communicate results through scientific visualizations.

What have you been working towards in your capacity as the leader of OTN's modelling group?

One of my main goals has been to connect data users to new tools and see an uptake of our methods in the broader community. Only then could we be sure that we were accurately describing our approaches and developing software that non-experts are willing and able to use effectively!

What accomplishments are you most proud of in your work with OTN?

I take most pride in seeing students I supervise achieve their goals. OTN has given me the tremendous opportunity to hire highly qualified students to work on real scientific problems of interest. Marie Auger-Méthé is a shining example: having just completed a two-year postdoctoral fellowship in my lab as part of OTN modelling studies, she obtained an Assistant Professorship in the Department of Statistics and Institute for the Oceans and Fisheries at the University of British Columbia.

Dalhousie University professor Jinyu Sheng and Kyoko Ohashi from the OTN modelling group survey a research site in the Maritimes.

PHOTOGRAPH COURTESY OF MEOPAR

TRANSFORM

Transforming our understanding of the oceans by developing global data standards and a paradigm of collaborative research and data sharing, changing how scientists, communities and policy-makers in decision-making processes interact, as well as facilitating the use and development of novel technology

COMMERCIAL AND FIRST NATIONS FISHERIES

OTN tags a bull trout on Canada's Pacific coast. Bull trout predation may account for low river survival rates in salmon smolts.

PHOTOGRAPH BY NATHAN FUREY

Most species of Pacific salmon migrate to the open ocean only once in their lives. They travel from inland lakes and streams far into the Bering Sea before returning to their natal spawning grounds. In preparation for migration, male salmon undergo extreme physical changes, giving them their unique hook-shaped lower jaw, humped back and iconic red hues.

A cultural symbol, Pacific salmon are heavily targeted by commercial and recreational fisheries. In partnership with DFO, Indigenous peoples, ENGOs and fishers, OTN works to generate movement data, transforming fisheries management approaches and boosting conservation of Pacific salmon in British Columbia.

FRANZISKA BROELL

HOMETOWN: Augsburg, Germany

Postdoctoral Scholar and
CEO of Maritime bioLoggers

PHOTOGRAPH BY DALE WILSON, CFI

FITBITS FOR ANIMALS

Accelerometry research is used to identify specific animal behaviours like resting, feeding, and escape, and to monitor growth—essential information for advancing informed management of wild populations as rising water temperatures affect fishes' growth rates.

How did Maritime bioLoggers get started?

It began in 2010 as part of the OTN accelerometry project while developing a tag to measure fish growth rate. Growth rate is a key factor in determining the stock size of fisheries, and the information is therefore important for sustainable management. We soon realized researchers were interested in using these types of tags not only to track fish growth, but also to study movement and predation, so my colleague Andre Bezanson and I decided to start Maritime bioLoggers.

Initially, we wanted to provide the technology as an open-source project, but realized that the expertise required to build the sensors was beyond the capacity of most research groups. We started Maritime bioLoggers after realizing there was no product on the market that would provide the kind of data that our technology delivers.

Describe an exciting OTN collaboration involving Maritime bioLoggers.

I'm most pleased with the collaboration between Maritime bioLoggers, the OTN accelerometry project and the seal bioprobe project, which allowed us to deploy many of our movement tags on seals in the wild for the first time. The aim was to look at fine-scale movements to document seals' feeding behaviour. This enabled us to test the technology and deliver data that provided insights into the seals' hunting patterns.

How is your work impacting OTN studies?

The development of the technology has provided opportunities to branch out and work with many OTN projects as well as marine tracking groups globally, adding higher-resolution data to capture a more precise picture of what animals are doing underwater.

What's the most interesting thing you've learned from OTN accelerometry studies so far?

It's difficult to point out a single result from all the projects that I have been involved in, but our discoveries on the dynamics of animal locomotion (methods of moving from point A to point B) in the wild are most memorable. We found that Pacific halibut can accelerate twice as fast as a space shuttle launching into orbit! We also discovered that grey seals will dive down to 100 metres to rest—we are now beginning to understand the energetic requirements of these unexpected movements.

What's your most memorable experience as part of OTN research?

I had many memorable experiences in the field, such as tagging halibut in Alaska and going to the high Arctic, and seeing the development of my prototype deployed and recovered successfully in various places around the world. At the top of my list was meeting the German chancellor, Dr. Angela Merkel, during her tour of Dalhousie and OTN.

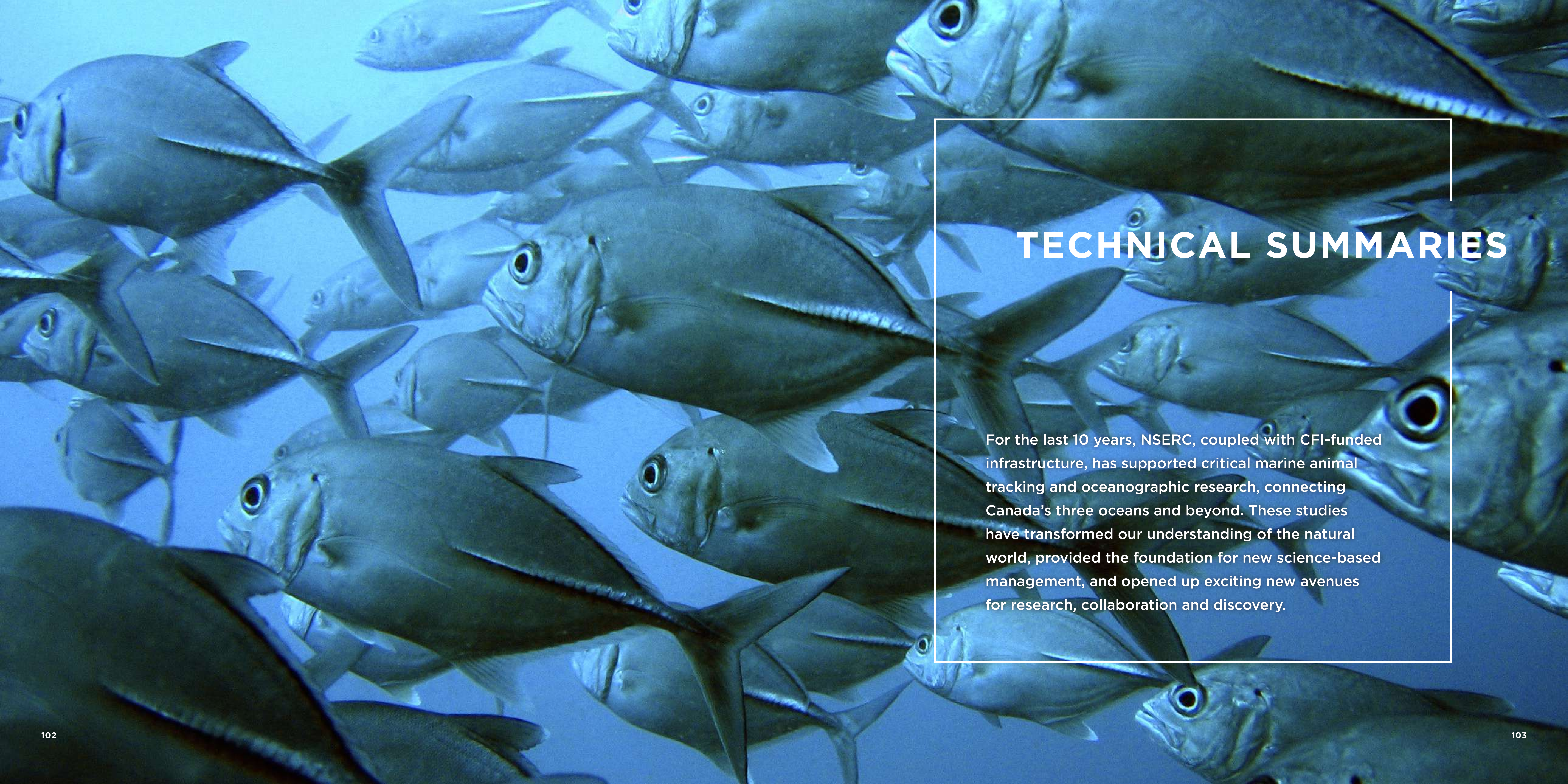
EMERGING ARCTIC FISHERIES

OTN Arctic investigators prepare to tag a juvenile Greenland shark in the Canadian Arctic.

PHOTOGRAPH BY STEPHEN FIELDS

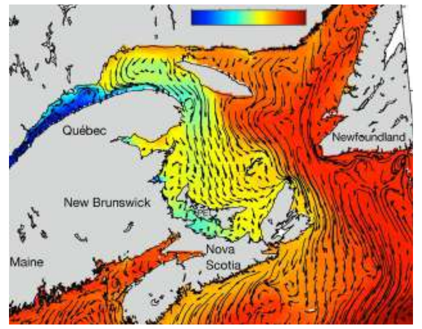
Arctic fisheries provide an important economic boost to northern communities and sustain traditional livelihoods. Despite the region's dependence on the ocean, little scientific data has been collected on the life cycles of culturally and commercially valuable species such as Greenland shark, Arctic cod, Arctic sculpin and many marine mammals.

While Greenland halibut are the primary commercial species in Cumberland Sound, Nunavut, their habitat and movements largely remain a mystery. OTN telemetry studies revealed distinct and predictable seasonal movement patterns of Greenland halibut, which brought them from one fishery zone to another. This key piece of information transformed management in the area, ensuring that Inuit harvesters received fair and just access to the resource, as well as assisting with the drafting of sustainable fishery plans for the region.



TECHNICAL SUMMARIES

For the last 10 years, NSERC, coupled with CFI-funded infrastructure, has supported critical marine animal tracking and oceanographic research, connecting Canada's three oceans and beyond. These studies have transformed our understanding of the natural world, provided the foundation for new science-based management, and opened up exciting new avenues for research, collaboration and discovery.



MODELLING THE BIG BLUE (4.1)

Using observations and mathematical ocean models, this project examined the effects of physical and biogeochemical ocean changes on OTN study species such as American eel, Atlantic sturgeon and Atlantic salmon. Models contributed to understanding the underlying mechanisms of observed movement patterns. Use of these models in several studies had direct implications for more effective management. For example, by combining observations and model-simulated projections of oxygen decline on the Scotian Shelf with known habitat requirements of endangered Atlantic wolffish, researchers showed that oxygen depletion is likely reducing wolffish habitat. Additionally, these models are a) helping in the analysis and interpretation of data from ocean sensors (OTN project 4.1), b) helping determine environmental conditions and their effects upon the swimming ability of adult Atlantic salmon (OTN project 4.4), c) have helped elucidate the effect of currents and oceanographic conditions on American eel migration (OTN project 4.5), and d) are allowing the characterization and prediction of winter aggregation sites of Atlantic sturgeon in the Bay of Fundy (OTN project 4.6).

ROBOPROBES (4.2)

In 2010, the OTN ocean-observing (glider) component launched one of the first glider-based oceanographic observation programs in Canada. In collaboration with MEOPAR, the glider program currently operates seven gliders: one Liquid Robotics Wave Glider, and six Slocum Gliders. One of the major questions framed by OTN Canada is how oceanographic and environmental features affect animal habitat use, movement and migrations. Gliders collect an array of physical, biological and chemical data and describe key ocean processes relevant to both animal-tracking research and weather and sea-state forecasting. Combined, OTN's gliders have spent more than 2,000 days at sea, traversing a distance of more than 48,000 kilometres and collecting 70 million data points along the way. OTN and its industrial partners pioneered the autonomous offload of data by the Wave Glider from bottom-mounted acoustic receivers (first achieved in 2014), and the Wave Glider is now a regular, cost-effective alternative to expensive manual data retrieval using ships. Gliders have been deployed on missions in support of the WHaLE project, which passively listens for whales in the rich feeding habitats of the North Atlantic in order to understand critical habitat use and provide real-time monitoring to mitigate ship strikes. Gliders are also used in other OTN studies to track tagged salmon, cod, eels, snow crab, sharks and seals throughout the Atlantic, Pacific and Arctic.

FITBITS FOR ANIMALS (4.3)

OTN accelerometry research has led to significant advancements in biologging tag design. Maritime bioLoggers, a spin-off company created and led by two OTN students, has emerged as a leader in Canadian biologging technology development. Within OTN, these tags have been used in a suite of studies that first successfully showed the relation of fish acceleration to changing body size, with the potential to estimate fish growth rates in the wild. Studies were then expanded to examine movement ecology in a range of ocean predators, including Atlantic grey seals, Pacific halibut and North Sea flapper skate. A large-scale study involving researchers across the Atlantic region used accelerometer tags to validate at-sea time budgets and prey-capture events in grey seals (OTN project 4.7). In collaboration with the International Pacific Halibut Commission, accelerometer tags deployed on halibut in Alaska allowed determination of their activity levels in the summer months, prediction of habitat use and importance of the area for adults. Accelerometer tags were also used to assess habitat use of endangered flapper skate in a collaboration with the Scottish Government, with the aim to deliver the scientifically based information required for evaluation and renewal of an MPA in Scotland.

LIVES OF ATLANTIC SALMON (4.4)

Unlike their Pacific counterparts that spawn and die after a single seaward migration, Atlantic salmon can migrate to the ocean multiple times and return to natal rivers to spawn again. The brackish waters of the Bras d'Or Lakes in Cape Breton are a UNESCO World Biosphere Reserve, connecting to the Atlantic Ocean through three narrow channels. The area was once known for its robust Atlantic salmon populations, but salmon have experienced troubling declines in recent years. Via partnerships with Eskasoni First Nation, DFO, local angling groups and conservation societies, OTN's tracking infrastructure has monitored salmon migrations between inland rivers, the Bras d'Or Lakes, and the Atlantic Ocean. For juvenile salmon, the Bras d'Or was identified as an important rearing habitat—of 159 smolts acoustically tagged between 2012 and 2016, half remained in the lake, while others migrated to the Atlantic and onwards towards marine pastures off Greenland. The decision to stay in the lakes was linked to a more robust body condition; thus, direct migration to sea may reflect immediate nutritional needs. For adult salmon, the movements of 60 individuals tagged after spawning in a natal river draining to the lakes showed that those in good physical condition tended to spend the winter in the river, with out-migration to the lake and Atlantic Ocean in spring. By contrast, energy-depleted fish moved back to sea in autumn immediately after spawning. Survival was highest when the fish overwintered in the rivers, and low when they left the river quickly after spawning. Once in the ocean, adult salmon also migrated to Greenland through the Gulf of St. Lawrence's Strait of Belle Isle. Results from both studies show marked seasonal and spatial variation in the way that salmon use the Bras d'Or Lakes, which has implications for their survival and management.

MYSTERIOUS MIGRATIONS OF AMERICAN EELS (4.5)

The long-distance migrations of endangered American eels have puzzled and fascinated scientists for over a century—no adult has ever been caught in the open ocean or at their putative spawning grounds in the Sargasso Sea. The movement patterns of juvenile (yellow) and adult (silver) eels from the St. Lawrence River to the Sargasso Sea were investigated beginning in 2010. Multiple complementary approaches were used, including acoustic and satellite telemetry, numerical modelling (OTN project 4.1) and chemical analysis. Acoustic receivers were deployed from the upper St. Lawrence River to the mouth of the Gulf of St. Lawrence, where 604 eels were acoustically tagged to determine the timing and pathways of this migration segment. Although detection rates were unexpectedly low, data revealed extensive variability and downstream migrations of more than 200 kilometres over 13 to 67 days using nocturnal ebb-tide transport to leave the Gulf. The oceanic migrations of adult eels were investigated using pop-up satellite archival tags, which recorded eels' positions over a three-month period before releasing from the eels and transmitting their archived data via satellite. Data from 60 satellite-tagged adult eels revealed substantial predation by porbeagle sharks before exiting the Gulf. The at-sea trajectories were reconstructed for 27 eels, including five tracked all the way to the Sargasso Sea, providing the first formal observation of adult eels entering their spawning grounds. These tags recorded epic oceanic migrations of more than 2,700 kilometres using similar paths and against ocean currents, indicating a degree of consistency but also complexity in the orientation and navigation mechanisms employed throughout the migration. Findings resulted in extensive media coverage, including in *National Geographic*.

A 'TAIL' OF TWO STURGEON (4.6)

Sturgeon are long-living, late-maturing animals with a complicated anadromous life cycle (living mostly at sea, and returning to freshwater to spawn). This OTN project primarily studied threatened Atlantic sturgeon in two areas of the Bay of Fundy—Minas Passage, Nova Scotia, and the Saint John River, New Brunswick. This research program has filled critical knowledge gaps on sturgeons' complex life history and population dynamics, spatial and temporal movement patterns, overwintering areas, growth, diet, survival and abundance. In Minas Passage, data have provided insight into the controversial overlap of the sturgeon population with deployed and proposed in-stream tidal turbines. This is helping researchers and managers assess potential negative impacts of tidal power infrastructure on these and other species of concern. The results are being used directly by DFO and other regulators to improve management regimes for conservation and protection of Atlantic sturgeon. In the Saint John River, studies have revealed the distribution and timing of migrating adult Atlantic sturgeon to and from the river, as well as the timing and location of spawning. In addition, studies of both Atlantic and shortnose sturgeon determined movement and aggregation areas of juveniles within the Saint John River, which offered the first evidence that overwintering juveniles made regular movements among sites and suggested competition for foraging areas and prey existed between the two species. These studies provided the basis to develop the OTN project on Pacific white sturgeon in the Fraser River, British Columbia (OTN project 4.14), and to incorporate accelerometry studies (OTN project 4.3) into sturgeon research.

SUMMARY

SEAL SCIENTISTS (4.7)

The bioprobe project advanced the concept of using large aquatic animals to carry tags that collect biological and oceanographic data while tracking interactions between predators and other tagged species in the Northwest Atlantic. This project also helped advance analytical methods, including modelling and visualization tools, for OTN data (OTN project 4.8). Beginning in 2009 and working closely with DFO, researchers equipped seals with satellite-GPS tags (recording transiting and diving), environmental sensors (measuring oceanographic characteristics), VEMCO Mobile Transceivers (transmitting acoustic signals and logging detections from other tagged animals), accelerometers (OTN project 4.3, measuring fine-scale behaviour and jaw movement), and even animal-borne cameras for short periods to validate behavioural inferences and consumption of specific prey. In addition, acoustic tags were deployed on more than 1,200 Atlantic cod over the same period. To date, data have been retrieved from 104 seals (85 per cent) tagged on Sable Island and from an additional 18 seals deployed with specially developed bluetooth-enabled tags in the southern Gulf of St. Lawrence. This long-term program documented how seasonal oceanographic features (temperature, phytoplankton biomass) and depth influence seal movement, as well as the links between environmental change and impact on top marine predators. Data have helped elucidate interactions of tagged individuals with other seals, and between seals and other tagged species of potential prey (Atlantic cod, salmon, eel, snow crab, lobster) as well as competing predators (bluefin tuna, sharks). For instance, encounters between seals and tagged cod did not record predation events but suggested co-occurrence in ocean 'hotspots'—areas of high productivity where many species forage. Better understanding of such relationships between top predators and potential prey is critical for effective policy decisions and resource management.

DATA MODELLING AND VISUALIZATION (4.8)

The efforts of the OTN modelling and visualization group focused on developing statistical models to analyze data across OTN. Initial work concentrated on studies of grey seal–cod interactions (OTN project 4.7, tag detection efficiency, species movement and predictions of movement behaviour, predator-prey encounter-rate probability), and on survival rates of tagged Atlantic salmon smolts leaving fresh water for the sea. These earlier efforts led to the formalization of a dedicated OTN visualization and modelling component, which continued its integration with the grey seal bioprobe project, but also significantly expanded efforts to develop complex statistical tools and models across all OTN projects. The group did extensive coaching in their methods, holding Network-wide workshops and training sessions. These important efforts helped advance OTN's research goals, as well as establish collaborations across projects both within the pan-Canadian research Network and internationally, enhancing member engagement with the OTN Data Centre. Annual data and modelling workshops by this group began in 2014, and acquainted participants with state-space modelling and computer programs to help researchers better analyze their complex animal- tracking data. A major workshop was held during the OTN-hosted 3rd ICFT (2015) in Halifax and included many international participants. A 2017 workshop held in Oaxaca, Mexico, brought together members of OTN and international experts in modelling animal movement and fisheries science. One of the main goals of this workshop was to identify future research directions that will benefit OTN, its researchers and other partners as OTN moves forward as a Canadian Major Science Initiative (2017-2022).

CONNECTING SPECIES, HABITATS AND PEOPLE (4.9)

Little is known about the relative habitat use of different species of anadromous salmonids in areas where their distributions overlap, particularly in the North. Predicted effects of climate change, such as reduced anadromy, altered growth and changing species mix, have increased the need for understanding comparative ecology of anadromous species. These species are central to recreational and subsistence food fisheries in Newfoundland and Labrador as well as the Arctic. The first component of this OTN project focused primarily on Arctic char and Atlantic salmon, species historically divided by resource and habitat preferences. The work was carried out in several nearshore river systems in northern Newfoundland and Labrador. The distributions of these animals are shifting due to climate change, with the southern salmon pushing north into char habitat. Using acoustic and archival geolocation tag technology, the project characterized overwinter movement and diel (24 hour) activity patterns, thermal habitat use and dispersal rate of Arctic char, which revealed correlations of movement with daylight, temperature and body size. Likewise, in Newfoundland Atlantic salmon, movement patterns, residency, feeding ecology and survival were quantified for the first time in relation to life stage and spawning history. The studies provided insight into how climate change may affect individual fitness and on the relative competitive abilities of these salmonids. The second project component focused on understanding the patterns and consequences of Arctic char dispersal, the most northerly distributed freshwater fish, in the Arctic region of Cambridge Bay, Nunavut. Key findings revealed clear preferences of char for coastal, surface waters when in the marine environment; regular and lengthy forays into estuaries throughout the summer; extensive stock mixing, including in freshwater; and that the largest (and most heavily fished) lake in the region appears to be used as an overwintering area for fish from many rivers in the region. These findings will guide future management for these species in the region.

ARCTIC INTERACTIONS (4.10)

The high Arctic is a region that is experiencing increasing stress due to rapid climate change and human activity. Research in the nearshore environment from 2010 to 2015 in Resolute Bay used a combination of acoustic and satellite telemetry, isotope analysis, oceanography and traditional ecological knowledge to study movements and interspecies interactions of key Arctic fish and marine mammals. Underwater acoustic noise and marine mammal vocalizations showed that beluga were only present in periods of low ice concentration, while bearded and ringed seals remained throughout the entire year. Arctic cod, a key prey of seabirds and marine mammals, collectively left nearshore areas when ice formed, changed habitats to avoid invasive jellyfish and vessel traffic, and made long-range migrations of more than 180 kilometres, revealing the first large-scale movements of individual cod. Shorthorn sculpin, a common benthic fish, were shown to have different movement patterns that related to foraging and feeding. Large-scale movements, presumably directed migrations, also occurred, and movement patterns of the fish changed when vessels were present or moving. The data collected on oceanographic characteristics, ocean noise and high-resolution fish movement are among the most intensive ever collected in the Canadian Arctic. This has provided new insight into the relationship between predators and prey and the influence of environmental and anthropogenic disturbance on animal behaviour in a rapidly changing and vulnerable high Arctic ecosystem. This in turn is improving equitable access to local resources for Inuit, as well as guiding sustainable fisheries management and tourism practices. In addition to the natural science conducted, OTN Arctic studies generated innovations in technology that increased acoustic detection in challenging Arctic environments, expanding animal-tracking range in some monitoring areas.

EMERGING ARCTIC FISHERIES (4.11)

Nunavut fisheries are rapidly developing, and managers in the region frequently have little biological information to guide their decisions. To address this, OTN researchers conducted novel studies on the population structure, movement ecology and depth preferences of commercially important Greenland halibut (as well as two common commercial bycatch species, Greenland shark and Arctic skate) around the Baffin Island coastal region. Interactions with marine mammals were also studied. In Cumberland Sound, a Greenland halibut fishery had been established, which was divided into northern and southern sectors by an arbitrary management boundary and regulated as if the two sectors had separate fish populations. However, OTN's telemetry data revealed that the fish were a single population that regularly crossed the boundary and that, overall, the Sound's halibut population was dwindling. In 2014, OTN Arctic researchers, working with Indigenous communities, successfully influenced the relocation of the management boundary to the entrance of the Cumberland Sound, which has helped guide more sustainable and effective management of the resource and ensured fair access to the fishery by local Inuit. Results also showed extensive migrations of Greenland sharks between Greenland and Canada and produced altered handling practices for bycaught individuals. As in other Arctic projects (OTN project 4.10), marine mammals were tracked by listening for their calls. The data revealed that narwhal and bowhead whales were only present before full ice cover developed in fall, while seals and walruses remained after ice formation. This project provided multiple discoveries about the secret lives of deepwater Arctic species and involved exceptional collaboration with local stakeholders and the government of Nunavut.

COMMERCIAL AND FIRST NATIONS FISHERIES (4.12)

The OTN Pacific Arena research (OTN projects 4.12-4.15) focused on anadromous Pacific salmon and white sturgeon due to their ecological, cultural and socioeconomic importance; public concern (sockeye salmon declines in the Fraser River in particular were flagged for action by the Cohen Commission); and their use of both inland and marine waters. The work depended on using a variety of tagging technologies (including acoustic, radio, Passive Integrated Transponder and biologgers) to track fish. The project documented movements and survival of the fish across spatial scales that previously were unattainable. To understand the effectiveness of regulations that required that non-target bycatch species be released when they were accidentally captured in authorized fisheries, OTN researchers studied post-release delayed mortality rates, behaviour and injury to four species of salmon on the coast of British Columbia. Bycaught chinook, coho, chum and sockeye salmon were examined in relation to different capture methods (beach seine, gillnet and purse seine), handling, recovery and environmental characteristics. Employing special gear and practices used by commercial and First Nations harvesters, researchers tested and identified realistic and sensible strategies for improved fish recovery. This enabled them to provide best practice recommendations to stakeholders and minimize mortality of these species upon release. Findings suggest that, contrary to current belief, assisted ventilation (manoeuvring fish to move water over the gills) prior to release has limited beneficial effects. Several studies on telemetry and tagging techniques, principally maximum tag load, were conducted to advance telemetry science and practices in the wild. OTN researchers made major contributions to a DFO Canadian Science Advisory Secretariat report that provided the latest scientific information to stakeholders and decision-makers on the survival rates of coastal migrating salmon, and assisted fisheries managers with decisions related to salmon conservation.

CATCH 22 (4.13)

Three popular sport fish (Atlantic salmon, Arctic char and coho salmon) served as the models of this OTN study, which investigated stressors associated with recreational catch-and-release fishing. It focused on the impacts of handling of the fish during capture and the influence of environmental characteristics such as water temperature and pathogen presence. This study provided the first post-release data for both Arctic char (Cambridge Bay) and coho salmon (Lower Fraser River). The work collaborated with an OTN Atlantic salmon study (OTN project 4.9) to include fish angled in lower river areas soon after sea entry and those caught in the nearshore coastal environments. This is one of the first studies to link health and pathogen presence to different fisheries stressors. Coho salmon mortality was low and treatment-specific impacts were negligible, presumably reflecting that fish were in a mature state in the final phases of their migration. Arctic char also had high levels of survival. Atlantic salmon had a high survival rate after release (approximately 93 per cent), although higher mortality was associated with warmer waters. Post-release mortality was independent of fishing gear, fish size and fight time. Anglers who used best practices could expect released fish to survive overall, although fly fishing yielded a higher number of survivors than lure fishing. Duration of air exposure was a good predictor of fish mortality after release. No standard for air-exposure maximums exists and many species can tolerate different exposure times. This study has resulted in numerous recommendations for best practices in recreational fisheries.

A 'TAIL' OF TWO STURGEON (4.14)

The Lower Fraser River white sturgeon population is complex and poorly understood, with portions of the population being found at varying times and seasons in the marine environment, in large lakes and in flowing sections of rivers. White sturgeon in the Lower Fraser River are listed as threatened under Canada's Species at Risk Act, and face various threats such as poaching, habitat destruction and loss of prey. Yet beyond mandatory catch-and-release fishing, there are few regulations on angling activity. This study in collaboration with the British Columbia Ministry of Forests, Lands and Natural Resource Operations filled knowledge gaps about white sturgeon movements and reproductive patterns, and investigated the effects of stress from capture by angling on survival rates. Starting in 2013, researchers tagged 174 adult white sturgeon with long-life acoustic transmitters that will be monitored well beyond 2018. Sturgeon were captured via angling. Blood samples were taken to assess their physiological stress state at the time of capture. Nearly all of the acoustically tagged fish were detected at multiple locations after release, many traveling more than 125 kilometres and at known or suspected spawning channels. Results indicated a high recapture rate in the fishery, but also suggest rapid recovery from stress and high post-release survival. Many fish were recaptured by anglers more than once. The OTN white sturgeon project directly contributed to federal management by gathering data on key aspects of sturgeon biology and movement, advised fishers and fisheries managers on post-angling mortality and identified areas and times of year when sturgeon were most susceptible to disturbance and stress.

PACIFIC SALMON: SURVIVING THE JOURNEY (4.15)

This project used acoustic transmitters to tag sockeye smolts in British Columbia's Chilko Lake. OTN researchers examined how environmental and genetic characteristics influenced salmon migration, behaviour and survival as the fish moved from rivers to the open ocean. This was one of the first studies to use new miniaturized transmitters in a large-scale (more than 2,500 tagged salmon) tracking project of juvenile salmon. The project revealed the technical feasibility of tagging the smaller smolts with the new tags; previous models were too big for 98 per cent of the population. Results indicated that more than half of the tagged fish did not survive river movements to enter the open ocean, a distance of more than 1,000 kilometres. Further results showed distinct patterns in both behaviour and survival—in small, clear, upper-river reaches, downstream migration largely occurred at night at speeds of up to 50 kilometres per day and coincided with poor survival. Only 60 to 80 per cent of smolts survived the first 80 kilometres of their downstream journey. A parallel laboratory study of tagged fish documented high short-term survival and unhindered swimming ability, eliminating negative effects of tagging as a mortality cause. This suggested that, in nature, predation was the main source of mortality in smolts. Additional field work documented large-scale predation by adult bull trout, which fed almost exclusively on sockeye smolts. Yearly workshops put on by the OTN Pacific salmon group include other academic stakeholders, government, community, and ENGOs. This group has also helped author CSAS reports in order to improve management of Pacific salmon at the federal level.

FROM SCIENCE TO SOCIETY (4.16)

A key goal of practical research is the uptake of novel information by end-users. This OTN project investigated stakeholder perceptions of biotelemetry, a disruptive new technology, and the uptake of information from biotelemetry studies for use in management and decision-making. OTN social scientists interviewed 110 individuals involved in the decision-making process (fisheries managers, senior bureaucrats, and stakeholders involved in co-management arrangements) in the British Columbia Lower Fraser River, the site of several OTN Pacific salmon studies. Findings suggested these groups had different expectations of scientific knowledge and its potential uses, with managers focusing on the immediate utility of the data to solve known problems, while stakeholders tended to see scientific knowledge as part of larger conversations about best practices. Respondents were also supportive of researchers' generation of original telemetry data; however, they were concerned about the relatively short battery lives of tags, which limited the durations of studies, and the time it took to retrieve data from receivers. These findings were shared with DFO (Pacific region) and are helping to refine the decision-making process regarding Fraser River fisheries. The OTN social science component also investigated other aspects of knowledge mobilization and transfer, including factors and processes driving data sharing in the global telemetry community. More broadly, the pros and cons of science communication among different stakeholders and the public were explored. This included investigating the exploitation of telemetry technology by poachers and wildlife photographers, and envisioning the future of aquatic telemetry science and application.

The lists below include past and present NSERC research network members, Council, SAC and ISAC members, as well as headquarters staff.

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The Global Ocean Observing System

Social Sciences and Humanities Research Council of Canada
Conseil de recherches en sciences humaines du Canada
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