COMMUNITY REPORT

Ocean Frontier Institute
2015–2022

OCEAN FRONTIER INSTITUTE

CANADA FIRST RESEARCH EXCELLENCE FUND

Photo credit: Nick Hawkins

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About this report

The Ocean Frontier Institute (OFI) Community Report celebrates the OFI community's accomplishments since the institution's establishment in 2015.

It showcases the achievements of researchers, students, staff and partners throughout the first seven years of OFI, acknowledging that much more has been accomplished than can be shown here. The OFI Community Report informs OFI's external community of policy-makers, the public, media and other organisations about OFI's contributions to ocean science, innovation and policy-making. This report is also an opportunity for new and potential partners and members of the broader ocean community to learn about OFI and how OFI's work contributes to Canadian and global ocean priorities. Finally, OFI has matured as a global organisation, and this report outlines OFI's vision for the future, of acting as a hub of ocean expertise and an international cross-sectoral community of ocean experts, undertaking world-class ocean research, innovation, and thought leadership.

OFI Land Acknowledgement

OFI acknowledges the ancestral peoples of the lands on which its current institutional partners reside:

***Dalhousie University**:*
Dalhousie is located in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq. We are all Treaty people.

We recognize that African Nova Scotians are a distinct people whose histories, legacies and contributions have enriched that part of Mi'kma'ki known as Nova Scotia for over 400 years.

***Memorial University**:*
We acknowledge that the lands on which Memorial's campuses are situated are in the traditional territories of diverse Indigenous groups, and we acknowledge with respect the diverse histories and cultures of the Beothuk, Mi'kmaq, Innu, and Inuit of this province.

***University of Prince Edward Island**:*
The land on which the UPEI community gathers is the traditional and ancestral territory of the Mi'kmaq People. We acknowledge the original custodians of this land and give thanks to the Elders – those in the spirit world who came before us and gave us the teachings of life; those here today, who preserve stories and traditions and guide us as knowledge keepers; and those who are Elders in the making.

The Need for Ocean Knowledge

We are a global leader in transnational interdisciplinary ocean research

The ocean is the largest ecosystem on Earth[1]. Constituting 99% of the habitable space on our planet, it hosts unmatched biodiversity – there are at least 240,000 known species[2] and 2,000 new species are discovered each year – ranging from microbes unseeable to the naked eye, to the blue whale, the largest animal that has ever lived.

As a global society we face the challenge of turning the tide on decreasing ocean health[2]. The ocean is warming, acidifying, and being depleted of oxygen. As a result, the marine food web is changing in complex ways, including species migrating to colder waters.

We must prioritise ocean health and ocean management, because so many species—including humans—rely on the ocean. A healthy planet depends on a healthy ocean.

By studying changing ocean ecosystems, currents, and oxygen levels; by supporting effective ocean governance; and by engaging in meaningful partnerships with local and Indigenous communities, OFI provides information that policymakers, stakeholders, and rights holders need to take actions to keep our ocean healthy.

Photo credit: Nick Hawkins

Photo credit: Nick Hawkins

In 2020[3], fisheries and aquaculture harvested a record 214 million tonnes, valued at US$424 billion and providing an average 20.2 kilograms of fish per person across the globe. Yet, in 2017, only 66% of fish stocks were within biologically sustainable levels. In Canada[4], of 194 stocks assessed in 2021, only 30% were considered healthy.

By supporting innovative fisheries research and practices, OFI works to ensure we can continue to provide ocean-derived food to a growing population.

Climate change and human-related pressures are rapidly transforming the ocean. In parallel, how we interact with the ocean is also changing. By 2030[5], ocean-related economic activity – the 'Blue Economy' – will be worth a projected US$4 trillion and employ over 40 million people.

Thanks to OFI researchers and students producing new ocean knowledge and forging partnerships with industry, OFI has become a hub of expertise on the cutting edge of ocean research, policy, and innovation. OFI's support for innovation is creating a new generation of ocean-conscious entrepreneurs.

OFI's formation and work has resulted in unprecedented global partnerships and collaborations with universities in Atlantic Canada, working together to find ocean solutions.

OFI's pursuit of ocean knowledge and for the safe and sustainable development of the ocean supports meeting these grand societal challenges that will allow us to sustainably use our one global ocean.

ONE OCEAN › UNDERSTANDING CHANGE › SEEKING SOLUTIONS

About OFI

Bringing together researchers, industry, and government to solve complex ocean problems

OFI was established in 2015 to create a transnational multi-disciplinary research and training environment, and provide a nexus for researchers to work collaboratively with key stakeholders and rightsholders in Canada and around the globe.

In 2016, Dalhousie University (Dalhousie), with partner institutions Memorial University (Memorial) and the University of Prince Edward Island (UPEI), was awarded a $93.7 million Canada First Research Excellence Fund (CFREF) grant for the *Safe and Sustainable Development of the Ocean Frontier* research program, administered by OFI.

OFI Core Impacts

- Frontier Research
- Dissemination of New Knowledge
- Global Impactful Partnerships
- Training the Next Generation of Ocean Experts
- Driving Policy
- Thought Leadership

Photo credit: Nicolas Winkler Photography, courtesy of the Ocean Tracking Network

Central to OFI's strategy is partnerships: connecting OFI researchers with academic institutions, industry, not-for-profits, government, and Indigenous communities. As a result, OFI has over 170 partners and collaborators, established through its programs, and through the work of individual researchers, resulting in over $81 million of external funding and in-kind support for its research, education, and training programs.

With the support of CFREF and its partners, OFI has propelled new ocean research, technology and business development, and research outcomes in Atlantic Canada.

OFI's Geographic Focus

OFI research focuses on the Northwest Atlantic and Canadian Arctic Gateway, including the Labrador Sea and eastern portions of the straits of the Canadian Arctic Archipelago.

OFI 2015–2022

In just seven years, OFI has established itself as a driving force in ocean science. By supporting transdisciplinary research, innovation and commercialisation, and policy development, as well as a cross-cutting focus on partnerships, OFI is advancing the region's and Canada's global recognition as an ocean research powerhouse.

Photo credit: Nick Hawkins

Research

At the frontier of ocean research; building ocean knowledge

Safe and Sustainable Development of the Ocean Frontier

Through the CFREF *Safe and Sustainable Development of the Ocean Frontier* program, OFI research focuses on improving our understanding of changes in ocean ecosystems and atmosphere-ocean interactions; developing solutions for marine safety, ocean data, and ocean-related technologies; and developing sustainable fishing and aquaculture practices.

24
multi-year LARGE RESEARCH PROJECTS

7
short-term, high-impact OPPORTUNITIES FUND PROJECTS

127
innovation-focused SEED FUND PROJECTS

OFI's Large Research Projects

Leading frontier research that advances policy decisions and drives innovation in the development of a sustainable blue economy

OFI's Large Research Projects are multi-year transdisciplinary projects with multiple target outcomes. Each is led by best-in-class researchers working with teams of talented graduate and undergraduate students, postdoctoral fellows, and technical and administrative staff to make important advances in the *Safe and Sustainable Development of the Ocean Frontier*.

OFI-sponsored Large Research Projects are outlined here, with a subset as Expanded Summaries to provide detailed examples of the range of OFI activities:

Transforming Ocean Observations

OFI researchers are developing autonomous instruments for measuring and tracking ocean currents. By connecting stationary (moored), and mobile instruments (such as ocean gliders), this research project provides decision-makers with more timely and complete information about the changing North Atlantic Ocean.

Sustainable Capture Fisheries and their Ecosystems

Determining the size of fish stocks in the ocean is a key governance and research challenge, particularly as they change over time. OFI researchers are helping Canada meet fisheries' sustainability goals by providing assessments based on novel computer models of specific cold-water fish stocks and their ecosystems.

Spatial Dynamics of Valued Atlantic Groundfish

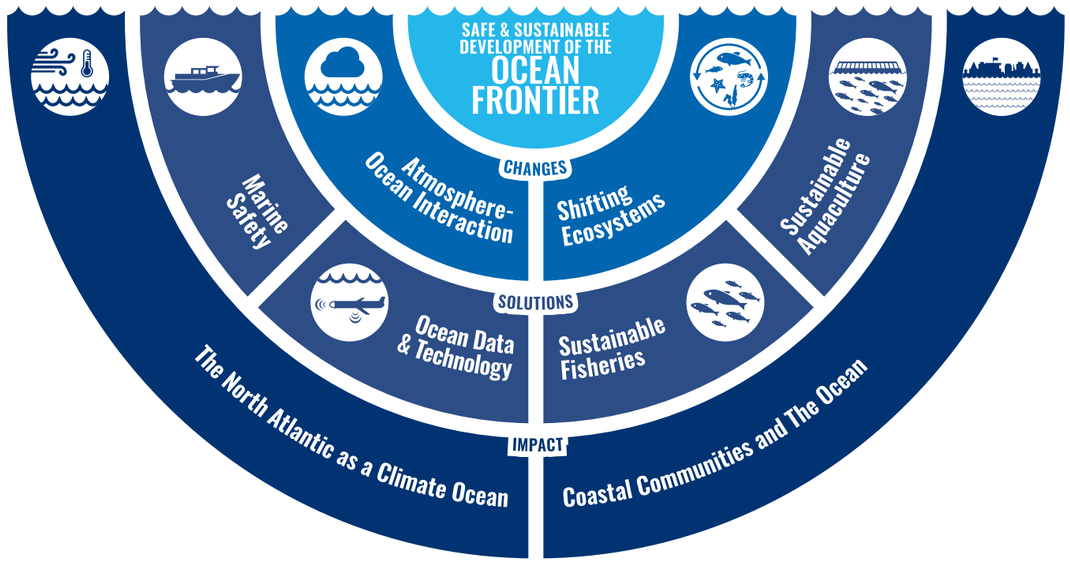
OFI researchers are working to support more responsive sustainable fisheries management. They are using acoustic tags to track the movements of Northern cod and Atlantic halibut to identify where and when they spawn, feed, and migrate, as well as genomic analyses to identify genetic features associated with those behaviours.

Social Licence and Planning in Coastal Communities

This project focuses on the significant challenge of social acceptability for marine aquaculture[6] in Atlantic Canada. Researchers explore this challenge through several themes and concepts including social licence, occupation health and safety, community-aquaculture dynamics, social carrying capacity, and marine spatial planning. The research aims to contribute to the debates on marine aquaculture and its place in coastal communities in Atlantic Canada.

Safe Navigation and Environmental Protection

This project explores a range of tools to help mitigate risks and adverse impacts from shipping and identify respectful approaches for safeguarding Inuit interests. It also contributes to marine spatial planning and determines how complementarities can be promoted and conflicts prevented — or managed — in shipping corridors.



Research Data Management

In response to a new generation of ocean-bound sensors that are generating an ever-growing and complex volume of data, OFI researchers are developing a data management system to effectively allow scientists from multiple disciplines to share ocean data and associated analytics algorithms.

Novel Sensors for Fish Health and Welfare

OFI researchers and industry partners are supporting ocean-based aquaculture managers by providing information and forecasts of the ocean environment at fish pens, and by monitoring for pathogens.

New Models of Salmon Health Management

Researchers are developing computer models for the spread of viral diseases and sea lice in marine-farmed Atlantic salmon populations, and evaluating data from novel sensors in salmon net-pens to reduce disease risk.

Informing Governance Responses in a Changing Ocean

Thirty years after the collapse of Newfoundland and Labrador's cod fishery, resource recovery is still creating challenges for effective governance and management of the province's fisheries, along with new concerns that include climate change, an ageing workforce, and access to resources and markets. Researchers are investigating how recent changes to Newfoundland and Labrador's fisheries impact the future of fisheries, coastal communities, and the provincial economy, and what kind of preparation is necessary to respond to new challenges.

Ecosystem Indicators for a Changing Ocean

By taking a broad view of ecosystem health, spanning from the base of the food web to human societies that depend on ocean resources, OFI researchers are creating an indicator framework to assess the health of Northwest Atlantic and Canadian Arctic Gateway marine ecosystems and how they are changing. The results will support local communities, inform policy decisions, and inform conservation strategies, such as the ongoing growth of Canada's network of Marine Protected Areas.

Dynamic Response of Microbial Communities to Change

To take stock of phytoplankton and other microbes which form the base of the marine food web in the Northwest Atlantic and Canadian Arctic Gateway, OFI researchers are using new genetic technologies and sensors to identify marine microbes, and forecast how they will respond to their changing environment and what impacts may develop that will cascade through the marine ecosystem.

Cooperative Model Framework for the Northwest Atlantic and Canadian Arctic Gateway

OFI researchers are developing a set of computer models of the Northwest Atlantic Ocean and Canadian Arctic Gateway to help predict future marine environmental conditions, forecast extreme maritime events (supporting safe shipping), and predict the effects of climate change on shifting ecosystems and variable fish stocks.

The Northwest Atlantic Biological Carbon Pump

An important aspect of the ocean carbon cycle is the biological carbon pump: atmospheric carbon dioxide is taken up by algae and other ocean organisms, which sink when they die, storing carbon in the deep ocean. OFI researchers are investigating the environmental conditions that affect the biological carbon pump, through measurements and computer modelling, with an aim to improve climate change policymaking.

One Ocean Health

Focusing on how a changing ocean environment impacts the spread of pathogens, our ability to grow ocean-sourced food, and antimicrobial use in ocean food farming, OFI researchers are supporting prudent antimicrobial policies and creating an equitable training program to promote the sustainable use of ocean resources in the future.

Future Ocean and Coastal Infrastructures

Humans are linked to the ocean through built infrastructures such as ports, vessels and navigation technology, natural infrastructures like coastlines, sea currents and fish habitats, and societal infrastructures such as seafood markets, marine shipping regulations, and cultural traditions and knowledge of coastal communities. Climate and ocean ecosystem changes are interacting with the changing built and societal infrastructures on which we rely. Coupled with extreme weather, coastal erosion, sea level rise, and more, these changes are creating new risks and challenges for the ocean industries and coastal communities that link us to the ocean. OFI researchers are re-thinking the way we design, develop, and manage infrastructures[7] to ensure the designs of our future infrastructures are sustainable, safe, and inclusive.

Marine Atmospheric Composition and Visibility

Atmospheric conditions over the ocean, such as fog, low cloud, and haze can impact visibility, climate, and air quality globally. OFI researchers are forecasting atmospheric conditions to support safe shipping and aviation. They are also studying the impact of changing air quality on coastal communities.

Auditing the Northwest Atlantic Carbon Sink

This project is creating an auditing toolkit — a scientific balance sheet — for the Northwest Atlantic's capacity to absorb carbon dioxide from the atmosphere, now and in the future. Measurement of how much of the carbon dioxide emitted by human activities is absorbed by the ocean is critical for the design and assessment of policies to mitigate climate change. Researchers are assembling a unique suite of measurements and models in order to assess carbon dioxide regionally.

Offshore Groundwater Resources in a Changing Marine Environment: Continental Shelf Surrounding Prince Edward Island

Using state-of-the-art geophysical, oceanographic, and geochemical equipment, OFI researchers are discovering and mapping offshore freshwater aquifers on the continental shelf surrounding PEI. The new data will be used to understand how these aquifers evolve in response to water extraction and changes in climate and coastal environments and have direct application for future sustainable development of PEI and other island and marine coastal settings worldwide.

Photo credit: Mahdis Mousavi

Improving Sustainability and Mitigating the Challenges of Aquaculture – *Expanded Summary*

Fish pathogens impact salmon aquaculture in Canada and worldwide. OFI researchers are studying how Atlantic salmon respond at a genetic and molecular level to pathogens, such as those that cause Bacterial Kidney Disease and Winter Ulcer Disease.

Matthew Rise, Professor and Interim Head of the Department of Ocean Sciences at Memorial, explains how their work is helping to identify which genes respond to pathogens:

"Once you have that catalogue of hundreds to thousands of genes upregulating or downregulating when the fish is infected, it can be used to develop specific biomarkers to assess the fish's response to the infection."

The results – called biomarker assays – can then be used to develop therapeutic diets and other approaches to increase salmon's resistance to pathogens.

A key facet to improving aquaculture's sustainability is fish feed. Stefanie Colombo, Canada Research Chair in Aquaculture and Nutrition and Associate Professor in Animal Science and Aquaculture at Dalhousie, says, "Prices for fishmeal and fish oil have more than doubled in the past two decades. This is a limited resource because it depends on the wild fish population, and there are concerns about availability and price. Our study was the first to show that a unique microbial oil from a company in Nova Scotia could be used successfully for salmon. It replaces fish oil, offering a more environmentally and economically sustainable lipid source." A collaboration with the National Research Council of Canada also led to identifying an algal species that could be used as a nutrient source for salmon.

Another challenge for aquaculture is drug resistance to sea lice treatments. Mark Fast, Professor and Chair of the Department of Pathology and Microbiology at UPEI, says, "This is a major problem in Atlantic salmon aquaculture. It is estimated that sea lice cost the salmon farming industry globally more than one billion US dollars a year." Researchers conducted molecular analyses to determine whether a new drug or vaccine could effectively treat sea lice. Says Fast:

"Drug resistance can develop quickly. The industry needs lots of tools to address this issue so that we can work in concert with an integrated pest management system to prevent resistance to any one therapy."

Future-proofing Marine Protected Area Networks – *Expanded Summary*

Marine Protected Areas (MPAs) are an important tool for protecting and restoring the health and diversity of the global ocean. "An MPA is a conservation area in the ocean. The main idea is to safeguard key species and ecosystems in that place from a range of impacts," explains Boris Worm, marine ecologist at Dalhousie and a lead researcher on this Large Research Project.

In Canada, MPAs have clearly defined boundaries. But changes in the ocean are driving marine species to move. "You can't do this with just static areas, the systems are changing too rapidly," says Worm. "We need to augment this solution with dynamic areas that track that rapid change."

OFI researchers developed models to improve forecasts of how ecosystems are changing and moving. In collaboration with the UN Environment Programme World Conservation Monitoring Centre, international workshops were held to develop key principles for designing dynamic MPAs. Worm describes a resulting paper that provides a climate risk index for marine life:

"This paper generated attention around marine conservation and developed a key tool and comprehensive methodology to assess climate-related risks for any marine species or ecosystem around the world."

Research on ocean management as it relates to protecting the critically endangered North Atlantic right whale[8] and blue whale[9] yielded legal and policy recommendations that take into consideration climate change. Researchers working on this OFI project also received $1.1M from Canada's smartWhales initiative to track whales using satellites. Says Worm:

"Our project has been very successful in advancing climate change adaptation as a major issue in policy discussions at Fisheries and Oceans Canada, and within the international community."

Photo credit: Nick Hawkins

Benthic Ecosystem Mapping for Sustainable Ocean Stewardship in a Shifting Ocean Climate

OFI researchers are mapping the ocean floor, filling a mapping gap in the Northwest Atlantic, to better understand the role of seafloor habitats in how species respond to climate change. To get a full picture of the benthic habitat, the researchers are working with Indigenous groups to understand the role of Local Ecological Knowledge and Traditional Knowledge, connecting natural and social science, and collaborating with multiple ocean industries and stakeholders.

Marine Biomass Innovation

Researchers are bringing together Indigenous and coastal communities, academic partners, industry, and other stakeholders to collaborate and co-develop sustainable, innovative, marine-based entrepreneurship opportunities and technologies. The project employs a collaborative research approach, integrating natural sciences with social sciences and scientific knowledge systems with Mi'kmaw knowledge systems, with the goal of re-purposing marine by-products to improve the sustainability of fishing and aquaculture operations.

Opportunities Fund Projects

OFI has awarded seven Opportunities Fund grants to provide researchers a unique opportunity to link their expertise to externally led projects. By encouraging collaboration and sharing resources (e.g., data management, ship time, tools, and technology), this program leverages complementary research with the timely availability of external funding and opportunities to advance our collective understanding of the ocean. Grants were awarded to projects that aligned with OFI partners, connected OFI researchers, brought in new researchers to OFI, and amplified opportunities not addressed by the Large Research Projects. Project themes include climate change in atmosphere and ocean interactions, climate ocean data capture and integrated IT tools, biodiversity, and sustainable aquaculture. Key activities include participation in a research cruise on the vessel Nuliajuk with the Geological Survey of Canada to collect geophysical, bathymetric, and sedimentological data as part of safe maritime operations under extreme conditions in Nunavut; development of an official bathymetric map for Pangnirtung Fjord; and a national workshop convened by researchers and hosted at Dalhousie for the BiogeoSCAPES program.

Sustainable Nunatsiavut Futures – *Expanded Summary*

For Labrador Inuit, coastal waters, ice, and coastal landforms are critical for travel, hunting, fishing, spirituality, and their sense of belonging. The Sustainable Nunatsiavut Futures (SNF) project is investigating the changing environmental conditions in Northern Canada and their impacts on coastal communities.

To launch the project, kick-off workshops were held to establish research ethics, knowledge co-production, and a project approach. The Nunatsiavut Government (NG) is co-leading the project and ensuring the research reflects the values of Labrador Inuit, in particular as the project's outcomes will inform the NG-led Imappivut Marine Plan.

"Community-based partnerships are key to the success of this project,"

says Eric Oliver, Associate Professor of Oceanography at Dalhousie. Locally based Inuit Research Coordinators are facilitating fieldwork across four communities in Nunatsiavut, and have been involved in several oceanographic cruises taking place in coastal Nunatsiavut waters. And in Nain, local experts have helped to create a Local Observer Monitoring Program to collect Inuit observations of ice, weather, and animal patterns and shifts.

In May 2022, project members, including the Nunatsiavut Government, the Inuit Researcher Coordinator team, and students from Dalhousie and Memorial, met in Halifax to plan research questions and build meaningful relationships. Project researchers and local expert Ronald Webb co-authored an essay on co-producing research questions and solutions in the region, published in the November 2022 issue of the *Journal of Ocean Technology*[10].

Nunatsiavut is hosting uKalagalâk ("discuss several things") events, where project members share their research with the local communities, connecting through artistic and outdoor research activities, and collecting feedback on improving project initiatives. "By combining scientific and community perspectives, we are helping to develop a truly collaborative approach," says Oliver.

Photo credit: (L) Ludovic Hermabessiere; (R) Amanda Cotton

Innovation and Commercialisation

OFI recognises that industry is a primary contributor to solving the world's toughest ocean sustainability problems. By supporting and collaborating on innovative research, OFI is helping to accelerate industry innovation and promote economic development in the ocean ecosystem in Canada. In particular, OFI's Seed Fund program is designed to support ocean innovation and entrepreneurship.

OFI Seed Fund

Offering funding for innovative ocean-related projects

OFI's Seed Fund[11] program forms the base of OFI's innovation and commercialisation pathway. The Seed Fund program aims to inspire, initiate, and invest in new ocean ventures. Seed Fund grants are small funding awards to help germinate innovative ocean ideas in research, commercialisation, and social entrepreneurship that will develop into new tools and strategies to support the Blue Economy.

OFI's Seed Fund program has supported 127 research projects to date in Indigenous knowledge, engineering, biology, fisheries and aquaculture, environment, social sciences, oceanography, and earth sciences, 32 of which were fully or partially funded by OFI partners. A few examples illustrate the huge variety of Seed Fund project themes to date:

- *A Two-Eyed Seeing Evaluation of the DFO (Maritimes Region) ecosystem-Based Management Framework Applied to Treaty Fisheries Implementation;*
- *Building a National Ocean Literacy Strategy; and*
- *Development of a Whale Aerial Sampling Platform (WASP).*

Photo credit: Nick Hawkins

OFI SEED FUND

Canadian Maritime Welfare Governance System: A Gap Analysis

Canada has a responsibility as a member of the Maritime Labour Convention to regularly review seafarer welfare gaps and limitations, but in December 2020 there was little information available on seafarer supports. Inspired by international work on seafarer welfare governance, Desai Shan, Assistant Professor of Medicine at Memorial and Jason Zuidema, Executive Director of the North American Maritime Ministry Association, applied to OFI's Seed Fund to explore this gap.

Seafarer welfare refers to services offered to individuals who are working on board a sea vessel, including international seafarers. Port-based centres can offer a place to rest, access to reliable wi-fi to connect with family and friends, mental health services, and in-person social supports. Seafarers can be at sea for up to 11 months at a time. "Feeling connected to a wider society, not just colleagues, can help them to find a healthy work-life balance," says Shan. The first step in the project was to establish a database of port facilities available in Canada. "We found that there were more than 300 marine terminals in Canada, and so the next step was to identify the gaps. In St. John's, for example, there were no port-based welfare centres." Shortly after the project started, the COVID-19 pandemic created unprecedented challenges for those working at sea. "Seafarers from outside Canada were considered international travellers. They were unable to take shore leave for this reason," explains Shan. "Port-based welfare services needed to be reformed in response." As seafarers were not allowed to leave their vessels, port chaplains and volunteers needed to visit them on board to offer services, deliver personal groceries, and negotiate access to vaccines and primary care resources. These welfare services remain critically important for the health and safety of seafarers. The research undertaken in this project led to the publication of a report in *Maritime Policy*[12], which was later disseminated among maritime labour governance stakeholders. In response, an initiative was started to formally establish a welfare centre in St. John's.

The success of this OFI Seed Fund also helped Shan secure a CIHR grant to build a larger project focussed on how COVID-19 is impacting seafarers. As part of this work, Ph.D. students at Memorial will have the opportunity to further their research on mental health challenges at sea. Says Shan:

"The initial funding from OFI allowed us to grow the seed. We gradually accumulated more data, enabling us to engage a wider range of partners and leverage additional supports. By growing the work to a certain scale, we were able to produce a much more competitive grant application."

Photo credit: Nick Hawkins

Training and Education

OFI provides training and education opportunities for students and early career professionals to help develop the ocean experts and leaders of tomorrow.

Ocean Graduate Excellence Network (OGEN)

Launched in 2021, OGEN[13] is supporting studentships for 25 students, from 2-year to 4.5-year programs, with funding partners including the National Research Council of Canada, Mitacs, Graphite Innovation Technologies, and Fisheries and Oceans Canada. OGEN enhances Masters and PhD programs with training experience designed to equip the next generation of ocean researchers for the global job market.

International Postdoctoral Fellowships

International Postdoctoral Fellowships[14] offer opportunities for early-career PhDs from around the world to conduct innovative, full-time, collaborative research based at Dalhousie, with frequent travel to one of OFI's partner institutions in Europe or the United States. To date, OFI has awarded 37 fellowships, with international partners such as Woods Hole Oceanographic Institution, GEOMAR Helmholtz Centre for Ocean Research Kiel, Alfred Wegener Institute, and the Interdisciplinary Graduate School for the Blue Planet.

Industrial Postdoctoral Fellowships

Industrial Postdoctoral Fellowships[15] pair outstanding postdoctoral researchers with leading ocean companies to accelerate innovation and foster new partnerships. OFI has launched a pilot of this program with Graphite Innovation Technologies.

Visiting Fellowships

Visiting Fellowships[16] program helps to develop world-class ocean leaders by providing opportunities for international early-career PhDs to conduct research at Dalhousie or Memorial; or for an OFI researcher to conduct research at one of OFI's eight international partner institutions. To date, OFI has awarded 28 Visiting Fellowships.

Photo credit: Nick Hawkins

OFI SEED FUND AND OGEN

Graphite Innovation and Technologies

Graphite Innovation and Technologies, founded in 2017 by Mo Algermozi and Marciel Gaier, provides the most sustainable marine coatings available to the shipping industry.

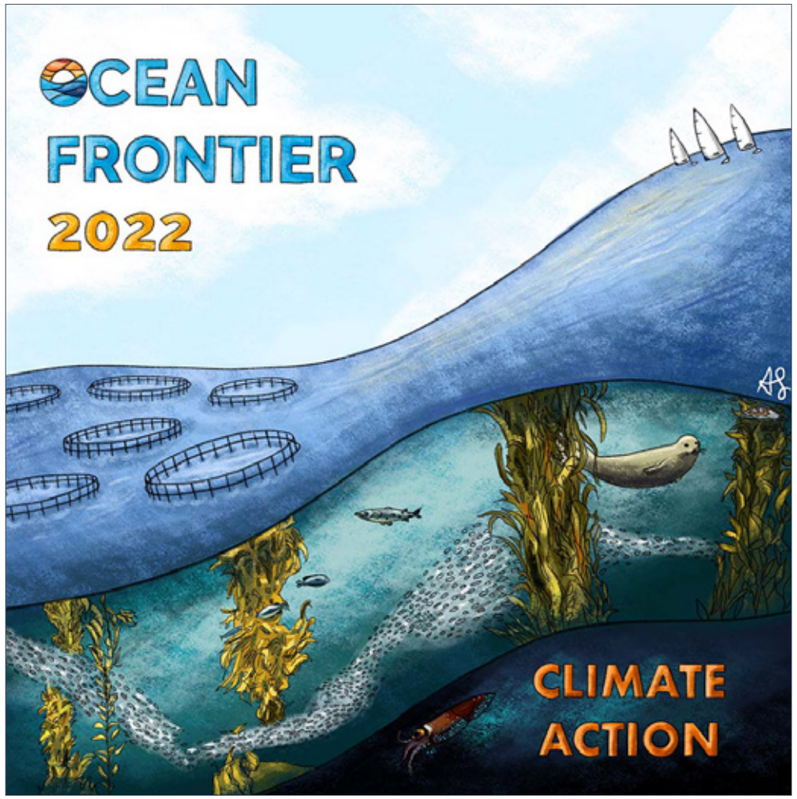
In 2018, Gaier, then a PhD candidate at Dalhousie, received an OFI Seed Fund grant[17] to design an ocean-friendly, sustainable coating that causes the marine life that grows on ships' hulls to slide off as the ships steam through the water. Gaier commercialised the innovative coating and is now the Chief Technical Officer of Graphite Innovation and Technologies (GIT). Gaier says, "Our coatings allow biofouling to grow, but they have a very low adhesion to the surface of the paint. Compared to traditional coatings that prevent biofouling by leaching copper or biocides into the water, GIT's slippery coating is environmentally friendly: when the ship moves, the biofouling slides off into the water."

Gaier says the OFI Seed Fund grant helped GIT in the early stages of technology development. In particular, to be "bolder in developing new products, and to do things we would not otherwise have done."

GIT continues to partner with OFI and has benefited from two OGEN-sponsored doctoral students and an OGEN master's degree student. Says Gaier:

"We see this as a long-term collaboration. As a recent startup, OFI, through its Seed Fund and OGEN programs, is contributing immensely to our research and towards our success."

Ryan Ingham, MSc, was the first student to complete his master's degree through an OGEN-sponsored internship. Ingham says, "I was able to have a unique master's experience at Dalhousie by collaborating with the University of Strathclyde on industry-leading research in the field of marine coatings and life cycle assessment, and with support from OGEN and Mitacs."



Original Artwork: Anneka Siegel

Supporting Students: Innovative Classrooms

- Almost 400 students involved in research or training opportunities supported by OFI
- OGEN sponsorship of 25 students to date working in government and industry labs with added value co-curricular activities enhancing their degree program
- Summer at Sea – sponsorship of 2 students on a once-in-a-lifetime learning experience at sea
- Youth Ambassador program – students receive mentorship and real-life work experience in their field, working with OFI Ambassador (Ocean Literacy)
- The 2020 OFI-hosted Ocean Decade North Atlantic Regional Workshop had Indigenous and youth participants, and All-Atlantic Ocean Youth Ambassadors were featured in a panel session, presenting projects they are leading in the North Atlantic Ocean.
- Sponsorship of youth-led workshops and conferences
- PhD candidate exchanges between OFI and Marine Alliance for Science and Technology for Scotland (MASTS)
- Ocean School providing immersive multimedia ocean learning opportunities for students in grades 5 to 12
- Student poster sessions at all OFI-hosted workshops and conferences

Photo credit: Alannah DeJong and Molly Wells

Summer at Sea – Voyage 2022

In spring of 2022[18], two undergraduate students, one from Dalhousie and one from Memorial, travelled to Valparaíso, Chile, to embark on a 16-week expedition aboard the research sailing vessel *Statsraad Lehmkuhl*. Sponsored by OFI, the students participated as crew members as they sailed the Pacific Ocean as part of an ocean sustainability course offered through Norway's University of Bergen, finally docking in Palau.

Illustrations credit: Molly Wells

Indigenous Engagement

The Ocean Frontier Institute honours and embraces Indigenous perspectives on the ocean and ocean research, recognizing these perspectives as vital for ocean health and sustainability.

Photo credit: Nicolas Winkler Photography, courtesy of the Ocean Tracking Network

OFI's *Strategic Framework 2018-2022*[19] and *Ocean Frontier Institute 2022-2027 Strategy* affirm OFI's commitment to respectful and meaningful engagement of stakeholders and Indigenous peoples in the safe and sustainable development of the ocean and as partners in OFI research. Most notably, OFI developed an Indigenous Engagement Guide[20] and licensed an online Indigenous cultural awareness training program to assist and guide those engaged in OFI-sponsored research towards successful partnerships and collaborations.

OFI is committed through action to supporting the:

- Truth and Reconciliation Commission's Calls to Action for Canadians,
- Tri-Council policy statement on ethical conduct of research involving humans, and
- UN Declaration of the Rights of Indigenous People.

Indigenous Cultural Awareness Training

OFI recognises that its work impacts Indigenous communities and organisations. As a result, OFI-affiliated researchers, students, and staff are provided with Indigenous cultural awareness training[21] that delves into First Nations, Inuit, and Métis histories and stories across Canada. The program contributes to meeting the Truth and Reconciliation Commission Calls to Action for Canadians to receive 'cultural competency training.' In particular, the course covers "the history and legacy of residential schools, the United Nations Declaration on the Rights of Indigenous Peoples, Treaties and Aboriginal rights, Indigenous law, and Aboriginal-Crown relations." (The Path: Your Journey through Indigenous Canada; NVision Insight Group Inc.)

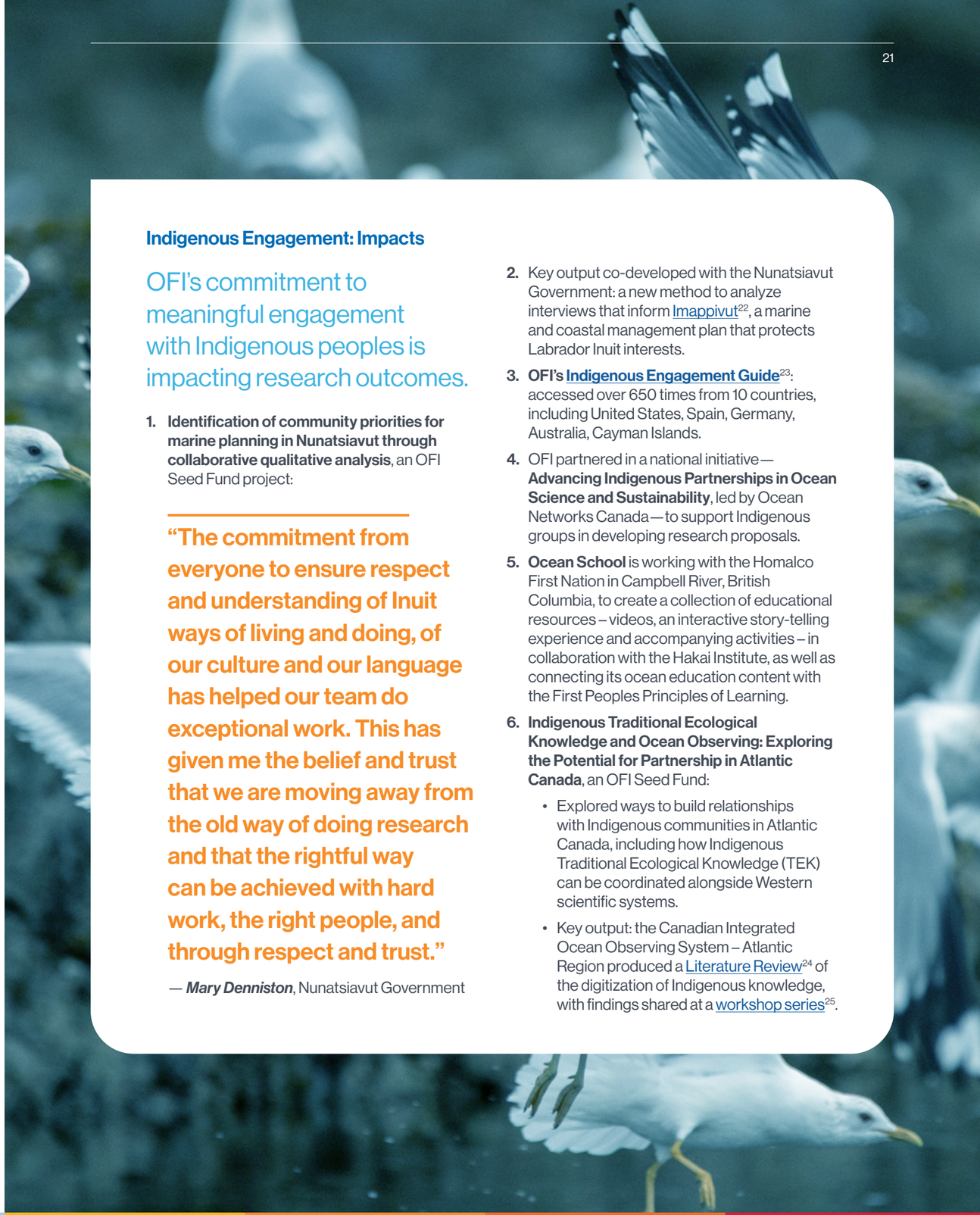


Photo credit: Nick Hawkins

Indigenous Engagement: Impacts

OFI's commitment to meaningful engagement with Indigenous peoples is impacting research outcomes.

1. **Identification of community priorities for marine planning in Nunatsiavut through collaborative qualitative analysis**, an OFI Seed Fund project:

> **"The commitment from everyone to ensure respect and understanding of Inuit ways of living and doing, of our culture and our language has helped our team do exceptional work. This has given me the belief and trust that we are moving away from the old way of doing research and that the rightful way can be achieved with hard work, the right people, and through respect and trust."**
>
> — ***Mary Denniston***, Nunatsiavut Government

2. Key output co-developed with the Nunatsiavut Government: a new method to analyze interviews that inform Imappivut[22], a marine and coastal management plan that protects Labrador Inuit interests.
3. **OFI's Indigenous Engagement Guide**[23]: accessed over 650 times from 10 countries, including United States, Spain, Germany, Australia, Cayman Islands.
4. OFI partnered in a national initiative—**Advancing Indigenous Partnerships in Ocean Science and Sustainability**, led by Ocean Networks Canada—to support Indigenous groups in developing research proposals.
5. **Ocean School** is working with the Homalco First Nation in Campbell River, British Columbia, to create a collection of educational resources – videos, an interactive story-telling experience and accompanying activities – in collaboration with the Hakai Institute, as well as connecting its ocean education content with the First Peoples Principles of Learning.
6. **Indigenous Traditional Ecological Knowledge and Ocean Observing: Exploring the Potential for Partnership in Atlantic Canada**, an OFI Seed Fund:
   - Explored ways to build relationships with Indigenous communities in Atlantic Canada, including how Indigenous Traditional Ecological Knowledge (TEK) can be coordinated alongside Western scientific systems.
   - Key output: the Canadian Integrated Ocean Observing System – Atlantic Region produced a Literature Review[24] of the digitization of Indigenous knowledge, with findings shared at a workshop series[25].

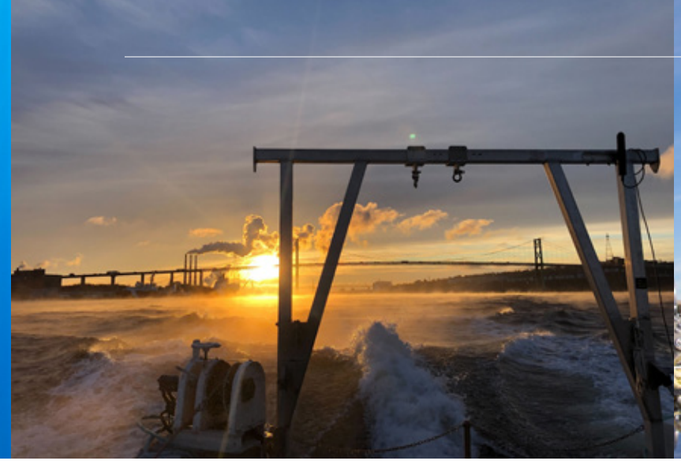


Photo credit: (L) Nick Hawkins; (M) Richard Davis, CEOTR; (R) Nicolas Winkler Photography, courtesy of the Ocean Tracking Network

Driving Ocean Policy

Engaging the ocean science and policy communities

OFI engages with the ocean science and policy communities, by hosting conferences, workshops and webinars, connecting with elected and non-elected officials within government, and contributing to international ocean science and policy meetings. These are just a few examples:

Ocean Frontier Biennial Conference

In October 2018, over 330 delegates from Atlantic Canada, across the country, and abroad, met in St. John's, Newfoundland and Labrador, to discuss the *Safe and Sustainable Development of the Ocean Frontier*. The conference covered topics such as How Science, Partnerships and Innovation Will Secure a Future for the Ocean; Our Changing Ocean; Identifying Ocean Solutions; and Industry Perspectives on the Importance of Ocean Research.

In May 2022, OFI gathered over 250 delegates in Halifax[26] to discuss six Focused Topics:

1. Achieving Net Zero
2. People and the Ocean
3. The Imperative of Ocean-Based carbon dioxide removal
4. Food from the Ocean
5. Innovation and Commercialization
6. Biodiversity

Dorene Bernard, a Mi'kmaq Grassroots Grandmother, Water Protector and Water Walker, conducted a water ceremony to kick off the event.

Ocean Decade North Atlantic Regional Workshop

Hosted in Halifax, Nova Scotia, in January 2020, 150 participants from 14 North Atlantic countries were invited to discuss priorities and actions for the North Atlantic Ocean in support of the United Nations Ocean Decade.

The North Atlantic Regional Workshop culminated in identifying a set of meaningful actions, potential initiatives, programs, and partnerships that will advance ocean knowledge for sustainable development.

People and the Ocean Speaker Series

OFI's Social Sciences and Humanities Working Group hosted eight webinars[27] in 2021 to 2022 to inform ocean and coastal governance and provide an introduction to social sciences and humanities-led research to understand the complex interactions between society, economy, culture, and marine and coastal environments. The webinars covered topics such as Interdisciplinary ocean and fisheries economics in action, Resurgent Mi'kmaw ancestral approaches to treaty relations and ocean governance, and The Role of Human Rights and Arts in Ocean Research for Inclusive and Integrated Governance.

Annual Carbon Workshops

Beginning in 2021, OFI has hosted annual Carbon Workshops[28] to discuss the ocean's changing ability to absorb carbon:

In partnership with the Global Ocean Observing System (GOOS), the first annual Carbon Workshop, held virtually in 2021, gathered key policymakers, opinion leaders, and ocean carbon scientists to discuss the critical role of the ocean in controlling our climate and the importance of including the ocean appropriately in net-zero calculations supporting climate targets.

The second annual Ocean Carbon Workshop[28] was held in 2022, in Halifax, Nova Scotia, as part of the World Ocean Tech and Innovation Summit[29] hosted by The Economist. The workshop focused on the urgent need to accurately collect and integrate ocean data in climate models in order to help mitigate climate change. Discussion insights and conclusions ultimately contributed to OFI presentations at COP27.

United Nations Conference of the Parties (COP)

OFI's Scientific Director & CEO participated in recent COP events, helping to bring attention to the ocean and the importance of integrated ocean carbon observations.

COP26 – At the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 2021, OFI led a delegation advocating for the inclusion of ocean chemistry variables in the climate targets planned to be set at the conference. OFI's Scientific Director and CEO participated in panel discussions with international policymakers and ocean influencers from around the world.

COP27 – At the 27th Conference of the Parties to the UNFCCC in 2022, the Scientific Director and CEO spoke at or moderated 10 events, including:

- An event sponsored by The Partnership for Observation of the Global Ocean (POGO) and the Global Ocean Observing System (GOOS) on the topic of ocean observations for climate change;
- A National Oceanography Centre event on Blue Carbon;
- The ocean's role in fighting climate change; and
- An Egyptian Space Agency event: *"The interplay of machine learning and earth sciences in assessing coral reefs and other marine habitats."*

OFI partnered for COP27 with key organizations:

- GOOS
- World Meteorological Organization
- Government of Newfoundland and Labrador
- UNFCCC

COP15 – At the 15th Conference of the Parties to the United Nations Convention on Biological Diversity (CBD) in 2022, OFI partnered with GOOS, and emphasized the role of new technologies in reporting on ocean variables, including the Scientific Director & CEO speaking at a side event sponsored by GOOS.

Photo credit: Jett Britnell

Photo credit: Nick Hawkins

Community Outreach and Ocean Literacy

OFI is building programs that educate and train the next generation of ocean stewards.

Ocean School

Ocean School[30], an OFI program in partnership with the National Film Board of Canada, combines leading-edge educational technology with inspiring visuals to create compelling learning experiences that teach ocean literacy. In 2022, Ocean School was endorsed as an official Activity of the United Nations Decade of Ocean Science for Sustainable Development.

Photo credit: Lewis Burnett

"Ocean literacy is quite simply our understanding of what the ocean means to us. It's about fostering that relationship, recognizing how our actions and inactions impact the health of the ocean."

– ***Boris Worm***, Killam Research Professor at Dalhousie's Biology Department, Scientific Director of Ocean School, and OFI Ambassador (Ocean Literacy)

Photo provided by Valentina Ceballos

OFI Ambassadors and Youth Ambassadors

OFI Ambassadors are influential researchers associated with OFI and who help shape OFI's future direction, promote OFI, and mentor early career researchers and Youth Ambassadors. Boris Worm is OFI's inaugural Ambassador: "My role as Ambassador is to grow OFI's engagement in ocean literacy issues," says Worm.

The OFI Ambassador mentors OFI Youth Ambassadors and co-creates a project with them to help them become effective advocates for their area of expertise.

"My time at the OFI was my first real work experience in my field, and my first time being regarded as more than a student, but rather a marine scientist with valid thoughts, opinions, and skills.

"Thanks to OFI and Ocean School, I feel empowered and confident to follow science communication as a future career path.

I learnt about the techniques needed for different types of science communication (media, policymakers, general public, etc.) and it opened up a whole world of possibilities for me. Currently, I am doing my master's of Marine Biology at the University of Padova, Italy, and I feel like I am one step ahead of the curve thanks to my time as a Youth Ambassador for the OFI."

– ***Valentina Ceballos***, inaugural OFI Youth Ambassador

OFI by the Numbers

2015 TO 2022 (CUMULATIVE)

Research

OFI has funded over

$75 MILLION

to support cutting edge ocean research and training programs – providing the scientific framework to drive ocean policy and innovation.

24 LARGE RESEARCH PROJECTS
Emphasising transdisciplinary, high-impact research across social, natural, and applied sciences

127 SEED FUND PROJECTS
Small grants for innovative projects with high potential for success. Over $615k in external funding received for 28 Seed Funds

7 OPPORTUNITIES FUND PROJECTS
Over $330,000 (with donor funding, over $400,000) awarded for short-term, high-impact projects, leveraging external partnerships and funding

Research Outputs

6 Patents

8 Start-up Companies

27 Government publications

46 Articles in popular media

81 Reports, briefs, etc.

87 Book chapters

128 Conference proceedings and publications

147 Interviews

297 Keynote speeches

700+ Conference presentations

OFI Ocean Experts

212 RESEARCHERS

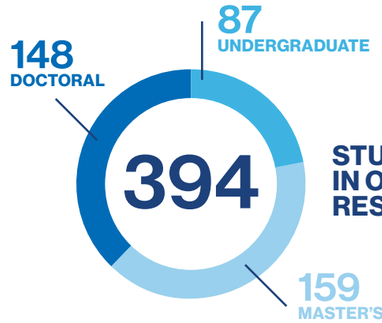
52 RESEARCH ADMINISTRATORS

Photo credit: Nick Hawkins

Training and Education Programs

Building the next generation of ocean experts and leaders

109 POSTDOCTORAL FELLOWS



STUDENTS ENGAGED IN OFI-SPONSORED RESEARCH

Fellowships for early career PhDs

Highly qualified researchers from Canada and abroad conducting innovative, interdisciplinary, and collaborative research

28 VISITING FELLOWS

37 INTERNATIONAL POSTDOCTORAL FELLOWSHIPS

Impact

Ocean Frontier Biennial Conference

OFI's global climate action conference[31], uniting leaders in science, industry, policy, and philanthropy to identify priorities and pledge action to solve the next frontier of ocean challenges.

2018 St. John's, Newfoundland — **OVER 330 DELEGATES**

2022 Halifax, Nova Scotia — **OVER 250 DELEGATES**

Carbon Workshops

68 ATTENDEES VIRTUAL AND IN PERSON

Partnerships

Total cash and in-kind contributions of over

$81.8 MILLION

from **170+** CONTRIBUTING PARTNERS

50 INDUSTRY PARTNERS who contributed cash or in-kind support to OFI

Formal academic institution partnerships

9 INTERNATIONAL

15 NATIONAL

Informing Policy

138 POLICY WORKSHOPS, BRIEFS AND REPORTS

Ocean School

1.7 million

Reach – aggregate number of website visits, newsletter subscriptions, teacher intro-video views, and more

The Future at the Frontier: Continuing OFI's Momentum

Photo credit: Richard Davis, CEOTR

The Future of OFI Research

In fall 2022, OFI launched the *Ocean Frontier Institute 2022-2027 Strategy*. Developed in consultation with its researchers, OFI has established three research pillars that will guide the focus of its work into the future. Over the next five years, OFI – with current and new partners – will fund frontier research, promote thought leadership, support knowledge mobilization, and develop our capacity to discover and support sustainable solutions for a healthy and productive ocean.

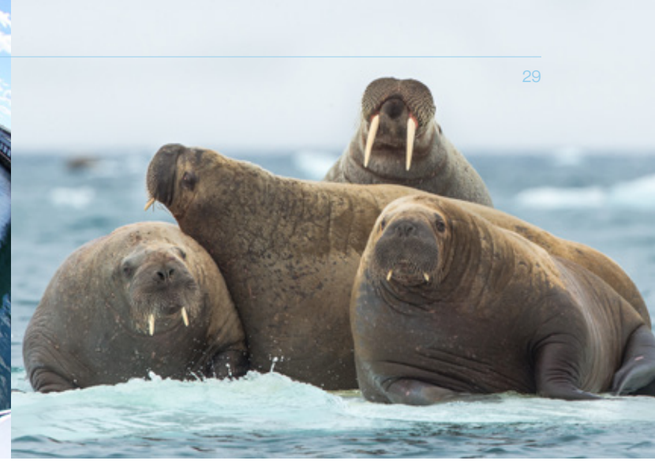


Photo credit: (L) Dalhousie; (R) Toby Matthews

OFI's overarching priority is to ensure progress for the ocean under three key **research pillars**:

Research Pillar: Achieving Net Zero

What we don't know can hurt us: achieving global net zero carbon dioxide – where carbon emissions equal carbon absorption – is impossible without the ocean.

Climate change is at the top of the international policy agenda: 137 nations have committed to global net zero targets, yet the impact of the ocean's changing ability to act as a carbon reservoir is missing in international climate scenarios.

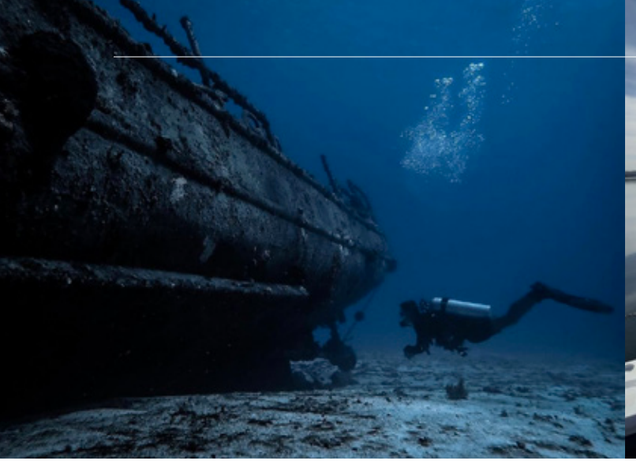
The ocean plays a critical role in absorbing carbon – it is by far the largest carbon reservoir on Earth. To date, climate calculations treat the ocean as a constant, rather than a variable, introducing a significant level of risk to our climate future. OFI research will help us understand the scope of the ocean's role in the global climate equation and how the ocean's ability to absorb carbon is changing with the Earth's climate.

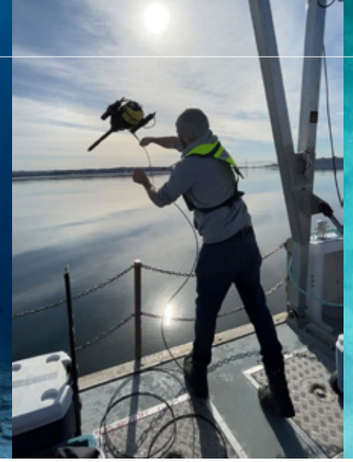
Research Pillar: Protecting Biodiversity

OFI research helps evaluate and protect marine biodiversity, looking at ecosystem models, sensors for monitoring fish, the movements of fish populations and more, to better understand life in the ocean and how it is changing. OFI will facilitate a high-level virtual workshop aimed at developing and building consensus on a comprehensive biodiversity strategy. This pillar aims to identify and describe key focal areas for moving forward with work in this area. OFI is in the early stages of launching this pillar.

Research Pillar: Sustaining Bioresources

Understanding capture fisheries and their ecosystems, coastal planning and aquaculture, fisheries management and governance, changing ecosystems, and shifting marine habitats are some of the ways OFI research will provide the knowledge needed for effective management and governance of fisheries, aquaculture, and marine protected areas. The knowledge OFI researchers create will help us manage ocean resources we rely on for food. OFI will launch this pillar in 2023-24.





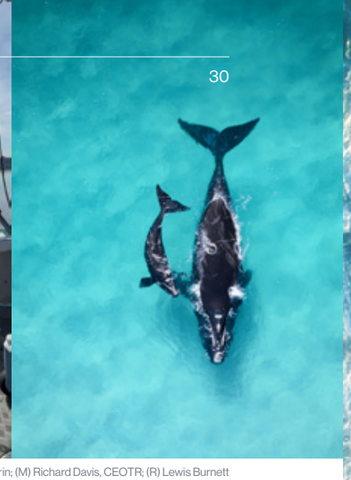


Photo credit: (L) Nico Marin; (M) Richard Davis, CEOTR; (R) Lewis Burnett

Achieving Net Zero: Research Plans – *Expanded Summary*

OFI is addressing Achieving Net Zero with two key initiatives: **North Atlantic Carbon Observatory**, and **Transforming Climate Action: Addressing the Missing Ocean**.

North Atlantic Carbon Observatory

To address scientific, policy, and economic risks confronting all nations, OFI has developed the framework for a ground-breaking project to observe, synthesize, and deliver ocean and climate data in near real-time.

The **North Atlantic Carbon Observatory (NACO)** – "envisioned as an international space station for the ocean" – would ensure that climate targets account for ongoing changes in the ocean. NACO would collect ocean data and deliver ocean and atmospheric information worldwide, through a globally integrated system, supported by a consortium of nations and partners.

NACO would monitor the North Atlantic Ocean carbon sink and generate realistic projections of the efficacy of climate targets, based on integrated near-real-time data.

Transforming Climate Action: Addressing the Missing Ocean

Our ocean has absorbed 90% of the heat from global warming, but its capacity as the world's largest carbon sink is not limitless. Through *Transforming Climate Action: Addressing the Missing Ocean*, world-leading experts from Dalhousie University, Université du Québec à Rimouski, Université Laval, and Memorial University, working with Indigenous communities, governments, industry, and other national and international partners, have proposed, through CFREF, a program of research and innovation aimed at reducing uncertainties in the climate budget, co-designing and evaluating novel approaches to mitigate climate change, and developing new understanding and practical methods to bolster justice and equity within adaptation at the ocean-climate-people nexus. This *Transforming Climate Action* research program is being led by Dalhousie University and administered and managed by OFI.

"We need to come together as a global community and prioritize high resolution observations of our changing ocean, which is responsible for absorbing one third of excess carbon emissions. It's a really urgent time for climate change. What we need to do is observe the ocean more closely now, to be able to understand how it's changing soon enough to know what we need to do to literally save the world."

– ***Anya Waite***, Associate Vice-President Research (Ocean), Dalhousie University

Creating Ocean Knowledge

Propelling OFI into the future, five **guiding principles** represent how OFI continues to translate world-leading ocean research and innovation into the ocean solutions we need.

1. Impactful and relevant research

Conducting applied interdisciplinary and transnational research, and engaging and partnering with key stakeholders, to address society's greatest ocean challenges.

2. Strategic partnerships

Delivering the research that industry, Indigenous communities and policymakers need, by collaborating with innovators and ocean knowledge users.

3. Driving innovation

Solving the world's toughest ocean problems by developing new ideas and giving those ideas and the people behind them the opportunity to drive positive change for our ocean and our future.

4. Investing in future generations of ocean frontier researchers

Growing and supporting the next generations of ocean experts to help them drive the research and sustainable economy we need for a healthy and productive ocean.

5. Influencing policy and decision-makers

Fully understanding our ocean ecosystem and how it is changing requires ocean knowledge at a global level. Providing world-class ocean research to decision-makers so they can make the hard choices needed to protect ocean and human health.

Photo credit: Kimberly Jeffries

Endnotes

1 https://oceanliteracy.unesco.org/principles/

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29 https://events.economist.com/world-ocean-tech/

30 https://oceanschool.nfb.ca

31 https://www.youtube.com/watch?v=_zCwOXYU_Vg&ab_channel=OceanFrontierInstitute

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