Science and technology plan

The scientific context

Sustainable management of ocean resources will be required if we are to conserve the benefits that the oceans biological resources bring to us. Managers and decision makers will require a profound understanding of interconnected marine systems if they are to mitigate the potential for harmful human impacts. This can only be achieved by providing a strong scientific base to underpin management activities. In addition to food security through commercial fisheries, marine species are also the basis of recreational fishing and tourism industries (e.g. whale watching, shark diving) worth billions of dollars globally per year, and are important culturally for First Nations and other aboriginal peoples. Considering the importance of many of these species, surprisingly little is known about their migration patterns and habitat use, survival rates, and how they respond to changes in the ocean environment. Therefore a global monitoring network provides the scientific foundation for sustainable management.

The scientific objective of OTN is to better understand changing ocean dynamics and their impact on ocean ecosystems, animal ecology, and oceans resources, with the aim to address critical issues in resource management and implications for ocean governance. Ocean ecosystems are hugely varied, ranging from polar to tropical, and abyssal to pelagic. Species of interest may confine themselves to restricted local movements, or be highly migratory. Within this overarching, shared objective, the international corps of OTN scientists is working in all parts of the ocean, on a broad array of valued species with widely differing behaviour. The scientists are also focused on strategic science issues critical to their nations and regions. Thus the scale and scope of the research undertaken by OTN's national and international partners and supported by the OTN platform will necessarily be tailored to meet the needs of the geographic areas in which the platform operates, and the species of interest. This is a great scientific strength, as the work of the network will provide a powerful opportunity to compare and contrast the responses of many different species from differing ecosystems to common stressors such as human exploitation and climate change. The comparative approach across many ecosystems provides the potential for a quantum leap in our understanding of ecosystem

The International Scientific Advisory Committee (ISAC)

To foster an integrated, internationally collaborative science focus, the OTN has established an International Scientific Advisory Committee (ISAC). The membership is drawn from the international scientific research community as well as from the existing Scientific Advisory Committee (SAC) that oversees the NSERC-funded network of Canadian OTN researchers. The ISAC assists OTN in identifying the important, global science questions amenable to being addressed by the OTN platform, and with aligning OTN international science efforts by identifying opportunities for research collaboration and integration, the training of HQP and the optimal use and sharing of network infrastructure. Areas for international integration will include data management and data analysis and visualization tools, and also potentially developing centres of excellence with Canadian and international partners. Results from the work in all of these areas will inform OTN activities (e.g., receiver line efficiency, data integration approaches, and conservation and resource management-focused analysis tools) and, in the longer term, will provide international leadership in marine animal tagging and telemetry research. The ISAC will also assist in encouraging and facilitating the participation in OTN of developing countries with limited scientific capacity, all of which will work toward solving global problems and contribute to a more sustainable use and management of strategic ocean living

structure and function, which in turn will inform new management regimes predicated upon ecosystem-based approaches.

The conceptual framework

In order to achieve the aims of OTN, it is important to establish a conceptual framework of scientific questions necessary to strategically align the related research activities within that framework and to inform ocean governance. Details of the science planning process are outlined in Appendix 3. In the short-term (over the next five years), the research questions being addressed across OTN will be broadly structured around three major integrated "framework questions" (FQ), under which projects will be organized and coordinated. Additional scientific activities will be structured under four major "cross-cutting activities" (CCA) (Table 2). CCAs are activities that cut across two or more FQs and/or projects and subprojects, which include methodologies and approaches that can inform the three framework questions. This overall organization ensures a conceptual understanding of how projects are interrelated, illustrates how best these can be integrated across countries and investigators to best address OTN's mission, and allows rapid dissemination to interested parties of all individual research projects and programs.

- Framework Question 1: How do oceanographic and environmental features (both physical and biological) affect animal habitat use, movement and migrations?

The main objectives of this framework question and its associated projects are to understand valued or keystone species in ecosystems and species at risk, and how their movements change in relation to oceanographic features and variability. Many animals are dependent upon extensive movements through the ocean, ranging from simple drifting to annual migrations to reach highly productive sites for feeding (growth), reproduction and to reduce predation risk. Understanding movements and migrations—and the physical and biological conditions that drive them—is crucial to conservation, economic development, and prediction of how animal distribution patterns will alter with climate variability and change.

- Framework Question 2: How do species interactions and areas of ecological significance relate to habitat use, movement patterns, and biotic/abiotic features?

The primary aims of projects relating to FQ#2 are to expand knowledge of predator and prey distributions in time and space in relation to ocean characteristics and to test hypotheses concerning predator and other impacts on prey populations, including economically important commercial fish stocks.

- Framework Question 3: How do anthropogenic activities and development influence animal behaviour and ecology*?*

Research related to FQ#3 aims to better understand the direct and indirect effects of anthropogenic activities and infrastructure on animal populations and their movements, migrations and habitat use and survival, in the face of changing ocean environments. Many human activities impact marine animals and their movements, distribution and survival, both directly and indirectly. Examples include harvesting and discarding, and their impact on food webs and functional relationships, habitat alteration, aquaculture, pollution, ship traffic, advent of alternative power sources such as tidal power plants, and ocean acidification and climate changes including loss of sea ice.

- Cross-cutting Activity 1: Assimilating animal tracking data with coastal and offshore oceanographic models

Models of the three dimensional, time-varying oceans have a critical role to play in understanding the movement and distribution of marine animals, and also in projecting how they will change with a warming climate. Such models are used to fill in the gaps between geographically sparse ocean observations and also to extrapolate to locations and times (especially the future) for which observations are not available. Used in this way, models can transform the OTN's point observations (e.g., detection of a fish crossing a line of acoustic receivers, measurement of temperature and salinity from a glider) into products that can be used for practical applications such as ecosystem-based management and the setting of marine policy. This CCA spans different species, geographic regions and disciplines and leads to results that will impact management and policy.

- Cross-cutting Activity 2: Visualization and modeling of complex aquatic and marine observations

This activity addresses the rapidly growing and critical need for visualization and modeling tools that will allow us to deal effectively with OTN (and other) tracking data and with the ensuing large complex data sets that will arise as we begin to link oceanographic features with animal migrations and movements. The growing data warehouse that OTN has created to house and link tracking data across the globe will be useful here.

This cross-cutting activity will initially draw on the OTN's international network of scientists from the USA, Australia and South Africa, where expertise currently exists. A new International Visualization and Modeling Team being developed within the Canadian OTN network (currently funded by NSERC) will form an important nexus for this activity. The visualization and modeling tools developed will be shared with the international tracking community. The vision is to eventually establish a distributed international Aquatic Animal Telemetry Centre of Excellence (AATCE, pronounced "At Sea") and to build ever-increasing membership from the international OTN community.

- Cross-cutting Activity 3: Advancing animal tracking technology and tagging techniques

Although OTN already employs cutting-edge technology, it also uses the needs of its investigators to drive collaborative R & D into new technology and the innovative use of the technology to permit scientists to answer next-generation questions. Thus a key activity of OTN internationally, relevant to all FQs and CCAs, must be a continued focus on technological advances, refinement of techniques in animal tagging including the development of best practices for animal capture and tagging, receiver array placement, improvement of line efficiencies, and development of completely new products. Technology development will occur throughout the OTN programs, building on Canada's technological leadership in this field and fostering international collaborations with industry and scientists.

- Cross-cutting Activity 4: Policy, stake holders and mechanisms for feeding into outreach and management; cooperation of natural and social scientists

The new knowledge generated by OTN researchers will inform a number of pressing legal and social issues. Additionally, the technological innovations have the potential to significantly change the ways local, national, and international management systems are implemented, and thereby to generate more effective and sustainable coastal and ocean governance. OTN findings will be articulated through publications of modelling tools that will be made available to fisheries managers and stakeholders and

that will be informed by the work of those same people. One result of such information exchange will be harvest management "prescriptions" that are consistent with the logistic and regulatory constraints of fisheries. The objectives under this CCA are to examine the adequacy of existing laws, management policies, socioeconomic patterns, and harvesting practices for protecting marine species, with a particular emphasis on those that are at risk or are keystone species in their ecosystem. The ultimate intent is to suggest ways to weave a stronger, more successful protective net informed by increasing scientific information.

Document history:

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Table 1. The Ocean Tracking Network Scientific Research Framework Questions (FQ) and Cross Cutting Activities (CCA)[1]

Cross-Cutting Activity (CCA)	FRAMEWORK 1: How do oceanographic & environmental features (both physical & biological) affect animal habitat use, movement & migrations?	FRAMEWORK 2: How do aquatic species interactions & areas of ecological significance relate to habitat use, movement patterns, & biotic/abiotic features?	FRAMEWORK 3: How do anthropogenic activities & development influence aquatic animal behaviour & ecology?
1: Assimilating animal tracking data with coastal & offshore oceanographic models	→	→	→
2: Visualization & modeling of complex aquatic & marine observations	→	→	→
3: Advancing animal tracking technology & tagging techniques	→	→	→
4: Policy, stake holders & mechanisms for feeding into outreach & management; cooperation of natural & social scientists	→	→	→

[1] Associated with each project and subproject will be information about end users and national and international collaborators (e.g., academic, government, first nations, industry, other), activities related to international information exchange, and opportunities for exchange of highly qualified personnel (HQP).