OCEAN TRACKING NETWORK Canada

Understanding Species Movements, Interactions, and Environmental Variability across Canada's Three Oceans

Annual Reports Year 6 (2015)

NSERC Research Network Grant: NETGP 375118 – 08

Sara J. Iverson et al.

NSERC CRSNG

Table of Contents

Project Reports

Ocean Tracking Network (OTN) Canada Network Overview

1. Network Overview

1.1 OTN Canada Phase II framework

In 2014, OTN Canada entered its second funding phase (years 5-7; 2014-2016). The initial phase (2010 – 2013) was centered around five key research themes. Phase II builds on the work of Phase I while taking a more integrative approach to cross-Arena research: a conceptual framework was established around three major integrated framework questions (FQs), under which projects are organized (Table 1). Many activities relate to more than one FQ. Additional scientific activities are structured under four major cross-cutting activities (CCAs; Table 1). CCAs are activities that cut across two or more FQs and projects and subprojects, which include methodologies and approaches that can inform the three FQs. The FQ/CCA matrix illustrates how studies can be effectively integrated across the Network to best address OTN Canada's mission. This approach also fosters a breadth of training opportunities for HQP (Highly Qualified Personnel; students and postdoctoral fellows).

Table 1. Framework Questions and Cross-Cutting Activities matrix used in Phase II.

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	→	→	→

1.2 OTN Canada Phase II framework objectives

- FQ1: Understand valued or keystone species in marine ecosystems, and species at risk, and how their movements change in relation to oceanographic features and variability.
- FQ2: 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.
- FQ3: 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.

2. Progress and Network Integration

OTN Canada continues to make great progress as demonstrated by the track record of first-rate science:

- OTN Canada researchers successfully developed an integrated Canada-wide research network with increasing international reach;
- engaged 25 principal investigators (PIs) who have collaborated with even more national and international researchers;
- achievements were recognized with awards issued to lead researchers including Steven Cooke, awarded the prestigious NSERC Steacie Fellowship, and Aaron Fisk, awarded the Pew Fellowship in Marine Conservation;
- several students received awards for their work and engagement in the telemetry community.

A key focus of the NSERC Network is the training of students and postdoctoral fellows, as well as technicians and research assistants. During this report year, OTN Canada was supporting, in whole or in part, the programs of over 90 of these trainees ("HQP"). Integration of the Network within and across FQs and CCAs continues to increase and evolve through directed workshops and meetings, data exchange, joint publications and presentations, exchange of HQP, and integrated field exercises.

Details of all the projects and Network integration are described in individual reports.

2.1 Meetings/workshops/symposia/conferences

Members of the OTN community have been involved with many meetings throughout the reporting period. Of special note is the fifth annual OTN Canada Symposium, which was fully integrated with the 3rd International Conference on Fish Telemetry (ICFT) hosted by OTN in Halifax, 13-15 July 2015. Led by co-chairs Nikki Beauchamp (OTN Sr. Communications Officer) and Kes Morton (OTN Sr. Project Manager), the conference was attended by 250 researchers and students (the largest delegation to date) from 25 countries, presenting the latest in global aquatic animal monitoring and conservation

research. Conference themes included behavioral ecology, large-scale movements, technology innovation, and governance. The ICFT was an unprecedented opportunity for Network members, particularly HQP, to gain exposure to the international telemetry community and valuable training during workshops. All OTN HQP in attendance were asked to prepare either an oral or poster presentation, which have been compiled and posted on the OTN website.

Gilles Patry, President of CFI, and Martha Crago, VPR Dalhousie, gave opening remarks. The OTN ISAC, Council, International Data Management Committee (IDMC), and Futures Committee all held their respective annual meetings while in Halifax. A special "OTN Futures Meeting" was open to the entire ICFT delegation to gain insight from members of the global aquatic telemetry community on future opportunities and the best way forward for the next phase of OTN.

Conference workshops deepened participants' knowledge of various technologies and scientific techniques, and brought together groups of researchers conducting similar tracking studies. Two poster sessions facilitated networking and interaction among delegates. A student-only poster session offered students a chance to showcase their work to the broader delegation. A second poster session featured student and non-student posters, as well as a special networking event that paired senior scientists and students/early career researchers to offer mentorship, and career and project advice.

OTN Scientific and Executive Directors, Sara Iverson and Fred Whoriskey, each received the Destination Halifax Ambassador Award for their efforts to secure Halifax as host destination for the 3rd ICFT.

2.2 HQP exchange highlights

OTN HQP Montana McLean and David Yurkowski each received internal funding for cross-Network collaboration and knowledge transfer, and lab/field exchange, respectively. M. McLean hosted a workshop for OTN HQP at the University of Windsor on post-processing techniques for large datasets collected using fine-scale passive acoustic receiving networks (VPS, Vemco).

D. Yurkowski travelled to Sable Island, NS, to assist DFO and the Bioprobe Team (4.7) with their long-term population study on grey seals and retrieve satellite and VMT acoustic tags from tagged adults where he gained invaluable experience capturing/handling, chemically immobilizing and retrieving tags from large phocids.

Outreach, exchange and conference activities are further described in 4.16.

2.3 Network integration and collaboration

OTN has made steady and significant progress towards greater Network integration during Phase II. There is unprecedented sharing of research results, techniques, models, and data between HQP and PIs of different projects (described further in the individual reports). Figure 1 illustrates collaborations initially described between PIs in the Phase I

proposal and those described in the Phase II proposal. Figure 2 is an updated diagram illustrating collaborations across the Network based on co-authorship. These diagrams will be updated annually to demonstrate growth and integration during Phase II.

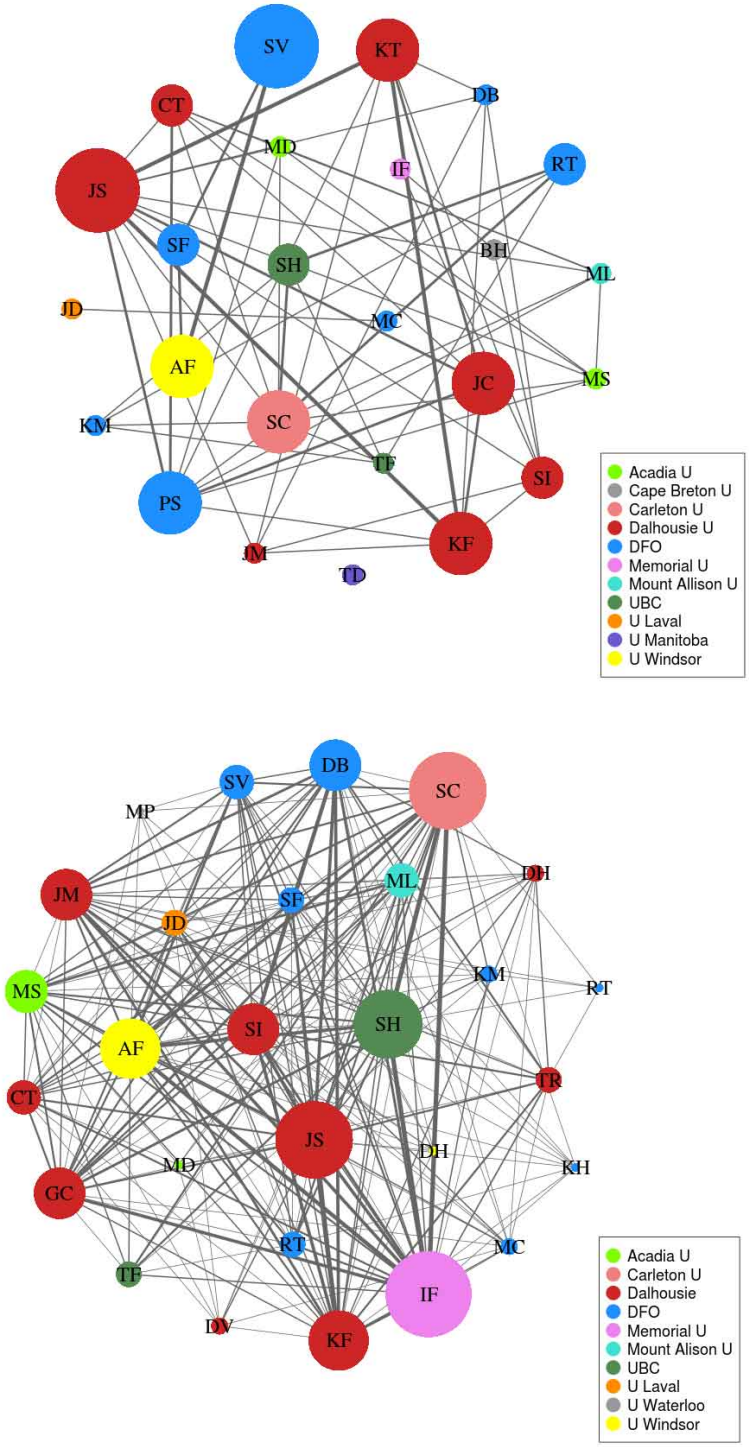

Figure 1. Comparison of OTN Canada integration as described in Phase I (top) and as described at the initiation of Phase II (bottom). Developed and presented by HQP Marianne Marcoux at the 2014 OTN Canada Symposium.

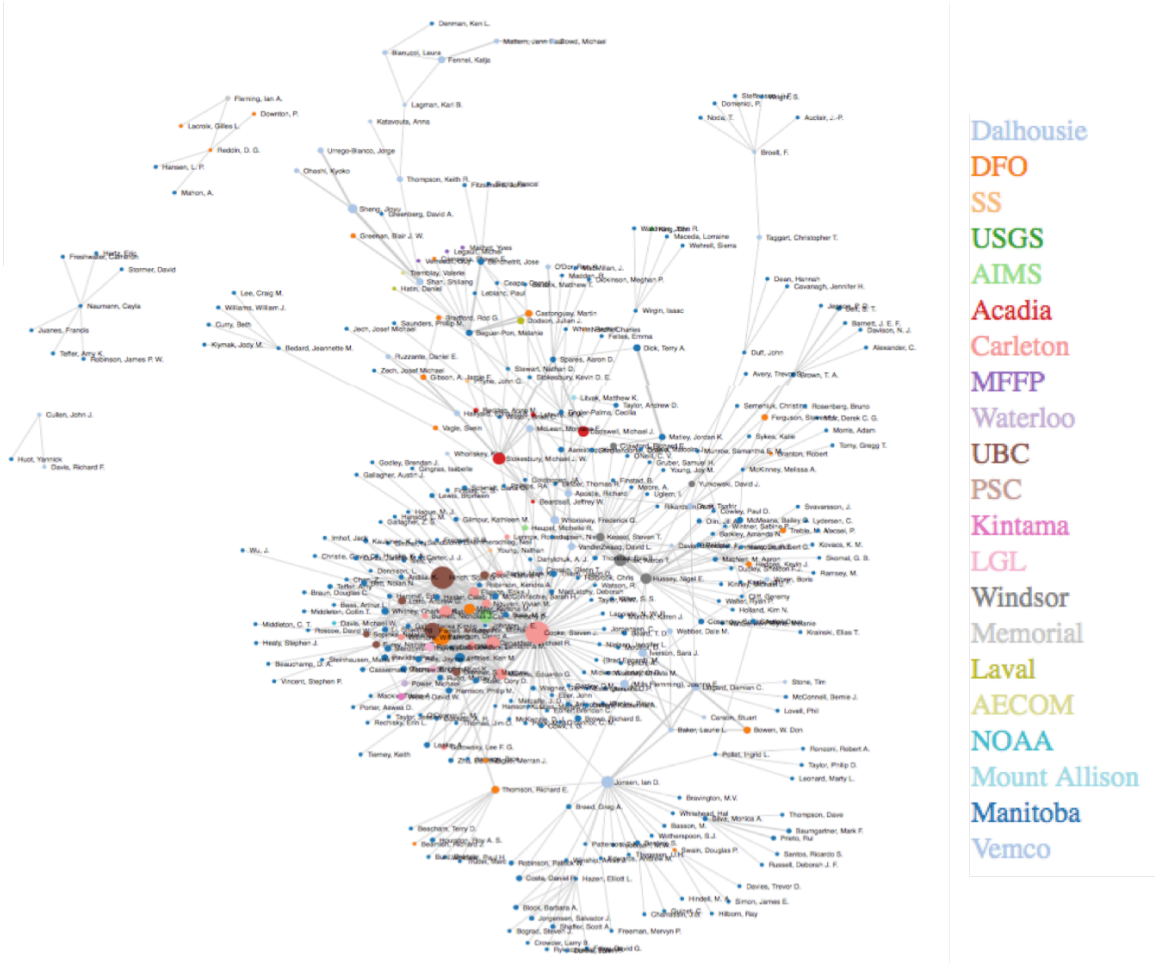

Figure 2. Co-authorship forced-directed graph created by OTN Portal Manager, Jon Pye. Nodes represent authors in the Network; edges are drawn between a primary author and each other collaborator per paper published in collaboration within the Ocean Tracking Network. Nodes are sized by number of publications on which they appear (2010 – 2015), and are color-coded by institution.

2.3.1 ideasOTN Committee ("Integrate, describe, expand, synthesize" OTN)

The OTN Futures Committee formed a subcommittee (ideasOTN) of senior OTN RAs and PDFs to collaborate on Network synthesis. ideasOTN is leading the development and implementation of new ideas for synthesis and output. There are currently15 ideasOTN projects either in progress or in preparation and over 40 collaborators that include members of OTN (HQP and PIs) and others from academia and government.

2.4 Canadian Research Program

(Project 4.1) Coupled Physical-Biogeochemical Ocean Modeling and Assimilation
Principal Investigator: Jinyu Sheng (Dalhousie)

The OTN physical oceanographic modelling component is reconstructing 3D circulation and hydrography over the eastern Canadian shelf, and developing numerical circulation and particle tracking models to provide a better understanding of circulation variability and to study the effects of physical conditions on the migration of marine animals. In 2015, these models led to the identification of key processes affecting migration of American eels and Atlantic salmon post-smolt in the Gulf of St. Lawrence, and determination of the potential winter aggregation area of adult Atlantic sturgeon in the Bay of Fundy.

(Project 4.2) Ocean observation component: OTN gliders
Principal Investigators: Dave Hebert (DFO-BIO, Dalhousie), Tetjana Ross (Dalhousie)

The OTN Observing Component collects a wide array of physical, biological, and chemical observations, primarily along the Halifax Line (HL). New results from echosounder observations are helping to locate feeding habitats and hot-spots for North Atlantic right whales on the Scotian Shelf. The OTN Wave Glider successfully uploaded >180 bottom-moored receivers along the HL thereby eliminating the need for manual recovery by OTN technicians and reducing costly ship-time. This component continues to support DFO Atlantic studies. The glider group participated in the third annual "Gliderpalooza," an international program sampling water of the eastern United States and Canada – 19 institutions launched 25 simultaneous glider missions during the 2016 hurricane season.

(Project 4.3) Accelerometry techniques and applications
Principal Investigator: Christopher Taggart (Dalhousie U)

The accelerometry research has led to enhanced accelerometer and inertial navigator tag designs used to identify specific behaviours like resting, feeding, and escape, and to monitor growth (by recording how fast a fish moves its tail). This information is essential to advancing informed management of wild populations as rising water temperatures affect growth rates of fish. Notably, in collaboration with the International Pacific Halibut Commission, tags have been deployed on Pacific halibut in Alaska to determine base levels of movement and behaviour. As well, 30 inertial and accelerometer tags have been deployed on 15 grey seals in a novel study to document activity and prey-capture events.

(Project 4.4) Survival strategies of Atlantic salmon in the UNESCO Bras d'Or Lakes Biosphere Reserve
Principal Investigators: Glenn Crossin (Dalhousie U), Bruce Hatcher (Cape Breton U)

Atlantic salmon numbers remain historically low with indirect evidence of high mortality at sea. This study explores the extent to which salmon adopt a post-spawning "recovery strategy"—over-wintering either in estuaries or in the Bras d'Or Lakes. Telemetry data

suggest fish that migrate to and over-winter in the lakes post-spawning experience higher mortality than fish that remain in estuaries and migrate in the spring. This information will have an impact on future management strategies.

(Project 4.5) Oceanic migrations of threatened American eel to spawning grounds in the Sargasso Sea
Principal Investigators: Julian Dodson (U Laval), Martin Castonguay (DFO-IML, U Laval)

Over a century of research had failed to document a single adult American eel in the open ocean making eels' migrations and spawning site a mystery. The OTN American eel project tracked 52 adult eels with satellite and acoustic tags. Data from the tags has revealed two distinct migratory phases as well as the first direct observations of an adult eel travelling to the Sargasso Sea. Results from this study were published in *Nature Communications* in late 2015.

(Project 4.6) Atlantic sturgeon movement and habitat use
Principal Investigators: Mike Stokesbury (Acadia U), Michael Dadswell (Acadia U), Matthew Litvak (Mount Alison U)

This project studies three distinct stocks of sturgeon from the U.S. and Canada that migrate to the Minas Basin, Nova Scotia, each summer. Population estimates put this aggregation at 38,000 individuals. These and other data are providing knowledge for management affecting the caviar industry, recreational fisheries, and tidal energy developments in the region. Researchers from this project are collaborating with OTN Pacific Arena researchers (project 4.14; white sturgeon) to determine sturgeons' physiological responses to angling stress and develop best practice handling techniques for sturgeon.

(Project 4.7) Grey seals as bioprobes: predicting ecosystem impacts
Principal Investigators: Sara Iverson (Dalhousie U), Don Bowen (DFO-BIO, Dalhousie U), Joanna Mills Flemming (Dalhousie U)

Grey seals are considered to be a potential source of mortality for commercial species such as Western Atlantic salmon and Atlantic cod. However, the significance of either species in the grey seal diet is still not well understood. By outfitting grey seals (15 in 2015) with dual-tag technology (VMTs and satellite tags), as well as accelerometers and animal-borne cameras, this project is providing important information on the ecology, species interactions, predation, and role of grey seals in the NW Atlantic ecosystem – 13 of the 16 VMT and satellite transmitters deployed on grey seals in 2014 were recovered. Moreover, this study is providing imprtant environmental information as the seals act as animal oceanographers, collecting data as they perform their daily activities.

(Project 4.8) Visualization and Modelling of Complex Marine Observations
Principal Investigator: Joanna Mills Flemming (Dalhousie U)

Ocean modeling and visualization play a critical role in understanding the movement and

distribution of marine animals by "filling in the gaps" in observations. Ocean modelling is being used in OTN studies of Atlantic sturgeon, Atlantic salmon, American eels, and grey seals to improve our understanding of these animals' response to changes in their physical and biogeochemical environment. The visualization and modeling group saw another successful year in 2015, bringing in experts in the field to work with the HQP and hosting multiple workshops to advance participant knowledge in a variety of modeling and visualization tools.

(Project 4.9) Predicting the impacts of climate change on salmonids in the north
Principal Investigators: Ian Fleming (Memorial U), Michael Power (U Waterloo), Ross Tallman (DFO-Arctic, U Manitoba), Aaron Fisk (U Windsor)

Salmonid species are of key importance for community subsistence in Nunavut and northern Newfoundland-Labrador where Arctic charr, brook trout, and Atlantic salmon are tracked at different life stages. Monitoring species' movements is important for addressing potential impacts of warming Arctic waters where much of the region depends on sound commercial management. In addition to telemetry data, the studies here are among the first to actively link movement with feeding ecology via the use of stable isotope analyses. Results from these studies are being discussed with local Hunters and Trappers Organizations to better manage the subsistence fisheries.

(Project 4.10) Fish and marine interactions in the High Arctic
Principal Investigators: Aaron Fisk (U Windsor), Svein Vagle (DFO-Arctic, U Victoria), Steve Ferguson (DFO-Arctic, U Manitoba)

The fourth consecutive season in Resolute Bay and Maxwell Bay, Nunavut, was a success with all equipment recovered and data offloaded. Studies of Greenland shark, arctic cod, arctic sculpin, and ringed seal, as well as oceanographic sampling undertaken, are among the most extensive ever collected in this Arctic region. The knowledge is providing essential data for predicting the impacts of a changing Arctic, as well as providing important tools for the assessment of the influence of anthropogenic noise in this ecosystem, and contributing to improved acoustic telemetry research in cold and deep waters.

(Project 4.11) Deep-water Arctic marine fishes: developing commercial fisheries

Principal Investigators: Aaron Fisk (U Windsor), Kevin Hedges (DFO-Arctic, U Manitoba), Svein Vagle (DFO-Arctic, U Victoria), Steve Ferguson (DFO-Arctic, U Manitoba), Daniel Heath (U Windsor)

This research provides some of the first insight into the movements and seasonal habitat use of the commercially important Greenland Halibut, and two bycatch species - Arctic skate and Greenland shark - around Baffin Island, contributing to the sustainable development of local fisheries. Data generated on the connectivity and abundance of inshore and offshore halibut populations have been used in management boundary decisions surrounding Inuit artisanal fisheries. Acoustic data are providing results on post release survival of Greenland sharks, which will directly inform commercial fisheries

handling of this bycatch species.

(Project 4.12) Delayed mortality, behaviours, and physiology of salmon in fisheries bycatch
Principal Investigator: Scott Hinch (University of British Columbia)

Combining physiology assessments and tracking data, this study is generating information on the mortality rates of four species of adult migrating salmon after they are released from fisheries capture. Researchers are also testing strategies for minimizing post-release mortality by improving the recovery of captured fish upon release. This study incorporates a strong social science element that identifies how stakeholders—government, First Nations, and ENGOs—can use telemetry research to better manage fisheries.

(Project 4.13) Evaluating the sustainability of catch-and-release angling practices in adult salmonids
Principal Investigator: Steve Cooke (Carleton University)

Conservation physiology is an emerging field in which the living systems of animals are used to understand underlying causes of survival and mortality. This study characterizes the fate of fish released from recreational fishing events relative to different handling techniques and environmental characteristics, with the aim of reducing fisheries stressors. Biological sampling underpins these studies, which are conducted principally on Arctic charr in the Canadian Arctic. The relationship between pathogen load and migration strategies of charr is being assessed.

(Project 4.14) Seasonal movements and spawning migrations of white sturgeon
Principal Investigator: Glenn Crossin (Dalhousie U)

Beyond mandatory catch-and-release rules, there are few regulations on angling activity of white sturgeon–"threatened" under Canada's Species at Risk Act–in the lower Fraser River. A typical angling event can last upwards of one hour– an enormous physiological stress. This study has linked reflex action mortality predictor (RAMP) scores to physiological indicators of stress (plasma lactate and glucose levels) and recovery times, which combined with acoustic telemetry will predict post-release behaviour and the fate of wild caught sturgeon on the Fraser River. This will have important implications for management and sustainablility of this fishery.

(Project 4.15) Survival and movements of out-migrating juvenile Pacific salmon
Principal Investigator: Scott Hinch (University of British Columbia)

This study examines how environmental and individual characteristics affect salmon smolts' first migration from inshore to open ocean. Analysis and write up of this five-year study is ongoing. Early results indicate that bull trout may account for high mortality in migrating salmon smolts. Bull trout are being tagged to examine this predatory-prey relationship more closely. A complementary study with DFO is assessing the effect of internal and external tagging approaches, while a branching study with local ENGOs

assess handling practices on bycaught salmon. This level of stakeholder engagement has brought new research and funding opportunities for the OTN Pacific salmon group.

(Project 4.16) Mobilizing new science for fisheries policy and management: the case of biotelemetry and Pacific salmon species in Canada
Principal Investigator: Nathan Young (Ottawa U)

Research suggests that interest in new scientific findings from biotelemetry is high among both regulators and stakeholders, but that significant barriers to adoption and implementation remain. This project will address this uncertainty about how biotelemetry findings "fit" with existing policies, regulatory decision-making processes, and stakeholder interests by investigating potential avenues for translating new scientific knowledge in the field of biotelemetry into real-world fisheries policy and management strategies, using Pacific salmon species in Canada as a case study. The research will be useful in identifying future research needs and opportunities of broad relevance to OTN as a whole (e.g., when the Networks of Centres of Excellence proposal is developed).

3. Training of Highly Qualified Personnel (HQP)

The integration of research activities among projects within and across Arenas from university, and government agencies has proven to be invaluable in terms of allowing HQP access to varied expertise across multiple fields of ocean sciences. Descriptions of HQP involvement are contained in the individual project reports. The following table (Table 2) summarizes the HQP who have been supported by the Network during 2015.

Table 2. Summary of the number of Highly Qualified Personnel (HQP) trained within the scientific program of OTN Canada by Project. Brackets represent the number of HQP receiving 100% support from OTN Canada.

HQP Total (Receiving 100% support from OTNC)	BSc students	MSc students	PhD students	Post Doctoral Fellows	Research Associates	Research Assistants	**Total (100% support from OTNC)**
4.1	-	-	3 (0)	1 (0)	2 (1)	-	**6 (1)**
4.2	4 (0)	2 (0)	2 (1)	-	2 (0)	1 (0)	**11 (1)**
4.3	5 (0)	-	1 (0)	-	-	-	**6 (0)**
4.4	1 (0)	-	1 (0)	-	-	-	**2 (0)**
4.5	-	-	-	-	1 (1)	-	**1 (1)**
4.6	1 (1)	4 (1)	-	-	-	4 (2)	**9 (4)**
4.7	1 (0)	1 (1)	-	-	2 (0)	-	**4 (1)**
4.8	-	1 (1)	1 (1)	1 (1)	-	-	**3 (3)**
4.9	-	3 (1)	2 (1)	1 (0)	-	-	**6 (2)**
4.10	-	2 (2)	2 (1)	-	1 (0)		**5 (3)**
4.11	-	2 (2)	2 (1)	-	1 (0)	-	**5 (3)**
4.12-4.15	-	6 (0)	13 (0)	4 (0)	3 (1)	5 (0)	**31 (1)**
4.16	-	-	-	-	1 (0)	-	**1 (0)**
Total (receiving 100% support from OTNC)	**12 (1)**	**21 (8)**	**27 (5)**	**7 (1)**	**13 (3)**	**10 (2)**	**90 (20)**

4. Participation of Key Partners

4.1 Government

The involvement of the Canadian Department of Fisheries and Oceans (DFO) occurs at all levels of research and coordination. DFO has two voting members (A. Vezina, DFO representative, and S. Vagle, Arctic Arena representative) on the NSERC Scientific Advisory Committee (SAC) and T. Swerdfager, ADM DFO, votes on OTN Council. Ten of the 25 Network PIs are university adjunct professors from DFO. Since many of the DFO scientists that are either co-PIs or collaborators are also adjunct faculty, they have a

significant involvement in both student and postdoctoral training. The details on involvement of partners in individual projects are described in section 11 of each individual report.

4.2 Canada Foundation for Innovation (CFI)

The OTN Global Network, through the CFI funding, has worked extensively with OTN Canada through deployment of fixed receiver arrays throughout areas of the Atlantic, Arctic, and Pacific Arenas and according to the needs of the OTN Canada PIs, through the purchase of acoustic tags and use of gliders, through the servicing and uploading of data that must be obtained from receiver lines, and finally through access to the data management support that is part of the infrastructure. The OTN International Scientific Advisory Committee (ISAC) works with the NSERC SAC to inform research decisions as they overlap. Since its establishment, ISAC meetings have been held in conjunction with OTN Canada Symposia to better inform key international partners on Canadian Network news and research, to offer global perspectives on Canadian research issues, challenges and successes, and to forge new paths for international collaboration and integration.

4.3 Industry

OTN Canada maintains national and international industry collaborations including VEMCO, Satlantic, Romor, Lotek, the Sea Mammal Research Unit, and others. Industry partners have been integral in helping solve problems, develop new technology, and brainstorm better uses of existing technology. A number of new industry partners were established during the reporting year (Emera) and two spinoff companies from OTN (Baker Blue Ocean and Maritime bioLoggers) continue operations and expansion. Examples beyond a supplier-buyer relationship are included in individual project reports.

4.4 Universities and other research institutions

The many universities and research institutions with which the OTN Canada PIs and collaborators are associated (11 Canadian academic institutions) provide further infrastructure and personnel support to conduct the Network's research, sponsor HQP, and host regional operations (described throughout the individual project reports). Eight universities listed in *Times Higher Education* World University (top 200) Rankings are primary collaborating institutions under the OTN umbrella.

5. Dissemination and Other Contributions

5.1 Publications and presentations

OTN Canada research is making impacts locally, regionally, nationally, and abroad. Important scientific discoveries are being made by OTN Canada researchers and published in high impact scientific journals. In 2015, OTN researchers documented the first direct observations of the movements of endangered American eels from Atlantic Canada to the Sargasso Sea. These results were published in *Nature Communications*.

Canadian and international PIs authored a review of global aquatic telemetry use, application, and future advancements, and which detailed OTN's vision for global cooperation in the future of aquatic animal telemetry and governance of the ocean's biological resources. The review, which was published in *Science* and scores in the top five percent of digitally and socially shared research outputs.

Network members regularly present to and exchange information among government scientists, other research networks, ENGOs, private industry, and local communities. Formal presentations at workshops and seminars are helping forge and solidify relationships with collaborators and stakeholders and augment visibility in the broader science community. Additionally, consultations with local community members help inform tracking study design and are an important part of planning, implementation, and communication with communities on which the research has direct implications. Stakeholder engagement and channels (e.g., documentaries, technical reports, public lectures, digital media) are described in project reports PIs have also used OTN Canada research programs to leverage additional funding support through submissions of new proposals for complimentary funding, student support, and access to new technologies and research spin-offs. These are far too numerous to describe here. However, a summary of accepted/published journal articles, conference presentations (Table 3), and other forms of dissemination (Table 4) by OTN Canada PIs and HQP is presented below and detailed in the individual reports that follow.

Table 3. Summary of accepted or published refereed journal articles and conference presentations (invited and contributed) by HQP and PIs by project.

Project	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12-4.15	**Total**
Accepted/published refereed journal articles	2	-	1	-	3	8	1	3	-	6	4	17	**45**
Conference presentations (invited and contributed)	5	3	2	3	2	8	2	8	1	12	8	45	**99**

Table 4. Summary of dissemination (partner meetings, public outreach of other deliverables) and awards received by HQP and PIs by project.

Project	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	4.12-4.15	**Total**
Formal meetings, workshops or seminars as part of collaborations with non-OTN members	3	3	1	6	1	2	3	1	1	3	2	55	**81**
Public dissemination (e.g., interview, community or school presentation, book, technical report, guidelines,)	0	15	2	0	2	8	10	4	2	5	6	44	**98**
Awards Received	0	0	0	1	0	0	0	0	0	1	2	18	**22**
Other (e.g. facility tour, meeting with government official, method/protocol, technology)	0	8	2	1	3	0	3	0	0	1	0	10	**28**

5.2 Newsletters and Website

The OTN newsletter serves to keep OTN members, collaborators, granting councils, government and industry sponsors, relevant members of the Dalhousie community, and other interested parties abreast of OTN news. The newsletter features regular updates on global deployments and tagging projects, data, and technology as well as conference dates, calls for proposals, and job postings. In fall 2014, the format and schedule for newsletter production and distribution was revised towards increasing visibility and timeliness of news reporting and now appears on a more frequent basis in a shorter, more digestible, bi-monthly format. All newsletters are hosted on the OTN website with a link sent via email to over 800 national and international recipients.

The OTN website (oceantrackingnetwork.org) was restructured in 2014 to reflect the evolving sophistocation of the Network and growing research initiatives and international partnerships. The content management system was also moved to Wordpress. Continuous monitoring of the analytics indicates a strong preference for a more readily accessible explanation of the Network's overall concept and core activities—for this reason, a moderate redesign of the website is planned for 2016 to feature a static landing page with OTN's mission, value, objectives, and concept clearly stated. A shift in the design will be

scored against the current analytics to improve user experience and boost digital engagement.

5.3 Data management/sharing

The OTN Data Centre made significant strides in management of OTN research data in 2015: the OTN database reached 100 million detection records. OTN also became an Associate Data Unit (ADU) of the International Oceanographic Data and Information Exchange (IODE), a programme of UNESCO's Intergovernmental Oceanographic Commission (IOC). OTN is one of 11 ADUs worldwide (the only one in Canada and the only one designated for electronic tracking), and is recognized as having established a data system built on high standards and best practices and will be actively engaged in future discussions on global data-sharing.

6. Changes, Reprofiling, and Delays

6.1 Deviation from the original overall research objectives

There have been no significant deviations to the Phase II objectives of the Network. Within the specific projects, adjustments have been made to maximize the productivity toward stated goals (in response to new personnel expertise and changes in logistical support).

6.2 Reprofiling and Budget Implications

The Reprofiling Sub-committee deals with ongoing changes to programs and funding, projects facing problems, and makes recommendations on these to the SAC. "Reprofiling" is meant to encompass issues, such as investigators proposing a deviation of >20% of their approved budget, investigators who have proposed to conduct certain work but are not performing this work, PIs raising concerns about the progress of specific projects and suggesting possible solutions or new directions, for special-purpose projects or activities outside the scope of the original proposal. Three requests were made to the Reprofiling Committee in 2015, the details of which are documented in project report 4.17.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.1

2. Project Title: Coupled Physical-Biogeochemical Ocean Modeling and Assimilation

3. Project Leaders: Jinyu Sheng (Dalhousie U)

Other OTN Canada participants: T. Ross, D. Hebert, J. Dodson, M. Castonguay, S. Iverson, D. Bowen, J. Mills-Flemming, G. Crossin, M. Litvak, M. Stokesbury, I. Fleming

Collaborators: Katja Fennel (Dalhousie U), Keith Thompson (Dalhousie U), Blair Greenan (DFO-Bedford Inst, Dalhousie U)

4. Public summary of report

During this report period, only the physical modelling component is funded by the OTN-Canada. Significant progress has been made by this component in four areas: (1) Construction of time-varying, three-dimensional currents and hydrography over the eastern Canadian shelf (ECS) during the observation period 2014-2015 using the state-of-the-art ocean circulation model in collaboration with the ocean observation component led by Dave Hebert and Tetjana Ross (project 4.2); (2) Examining the effect of physical conditions on the migration of American eels over the ECS by working closely with the research team led by Julian Dodson and Martin Castonguay on the biotic and abiotic control of the oceanic migrations of the threatened American eel (project 4.5); (3) helping the research team led by Mattew Litvak determine the winter aggregation area of adult Atlantic Sturgeon in the Bay of Fundy; and (4) Simulation of Atlantic salmon post-smolt movement in the Gulf of St. Lawrence.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Laura Bianucci	RA	100	100	1 Sept 2010	31 Dec 2014
Research Topic: Biogeochemical modeling in the Atlantic Canada region; Projections of suitable habitat					
Rui Zhang	PDF	50	3	1 Jan 2014	31 Dec 2014
Research Topic: Simulation of Atlantic salmon population					
Angela Kuhn	choose	50	50	1 Sept 2013	31 Dec 2014
Research Topic: Biogeochemical model optimization for the North Atlantic and the Atlantic Canada region					
Liuqian Yu	PhD	50	50	1 Sept 2013	31 Dec 2014
Research Topic: Biogeochemical data assimilation for the Atlantic Canada region					
Kyoko Ohashi	RA	100	40	2 Oct 2010	31 Dec 2016
Research Topic: individual-based model (IBM) in the study of Atlantic salmon post-smolt movement in the Gulf of St. Lawrence					
Shiliang Shan	PhD	50	20	1 Oct 2010	31 Mar 2016
Research Topic: Development of a multi-nested model to study coastal upwelling on the inner Scotian Shelf					
Yi Sui	PhD	20	10	1 Sep 2014	31 Dec 2016

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Research Topic: dispersion and hydrodynamic connectivity of surface waters on the Scotian Shelf using a numerical model					

b) Role, activities, and opportunities for training

There is no technical staff supported by this project.

6. Progress towards objectives/milestones

a) Overall objectives

Models of the three dimensional, time-varying ocean have a critical role in understanding the movement and distribution of marine animals, and also in projecting how these features will change in a warmer climate. Such models are used to "fill in the gaps" between geographically sparse ocean observations, and also extrapolate to locations and times (e.g., the future) for which observations are not available. Used in this way, models can transform point OTN 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. The overall objectives are to work on four species-specific applications in order to improve our understanding of how Atlantic sturgeon, Atlantic salmon, American eel and grey seals respond to changes in their physical and biogeochemical environment.

b) Progress

A state-of-the-art shelf ocean circulation modelling system for the Scotian Shelf has been developed and is currently used for predicting sea levels, three-dimensional currents, temperature and salinity in next 48 hours each day over the region. The modelling system uses four levels of multi-nested model grids, with the outer-most sub-model domain covering the northwest Atlantic Ocean and the innermost sub-model domain covering the inner Scotian Shelf close to Halifax Harbour. This modelling system is available for any OTN scientist upon request.

Most importantly, we developed a website in order for anyone to browse or access the model results (http://extrememarine.ocean.dal.ca/dalcoast/home.php). The model results since January 1, 2016 can be accessed directly from this website. Model results in 2014 and 20015 are also available upon request.

RA Kyoko Ohashi used an individual-based model (IBM) in the study of Atlantic salmon post-smolt movement in the Gulf of St. Lawrence. Kyoko worked with RA Melanie Beguer of Project 4.5 in tagging American eels that were released on the inner Scotian Shelf. Kyoko also worked with Andrew Taylor and Dr. Matt Litvak (Mount Allison University) of Project 4.6 on a manuscript documenting our study of the winter aggregation area of adult Atlantic Sturgeon in the Bay of Fundy. Kyoko attended the 3rd International Conference on Fish Telemetry held in Halifax in July 2015. She presented her recent study of Atlantic salmon post-smolt movement in the Gulf of St. Lawrence. Kyoko also attened a MEOPAR workshop held in Vancouver in August 2015.

PhD student Shiliang Shan has been studying coastal upwelling on the inner Scotian Shelf using the multi nested model that he has developed. Shiliang presented his results at the 49th CMOS Congress in

Whistler in June 2015 and the MEOPAR workhop in Vancouver in August 2015. Shiliang also worked closely with Melanie Beguer on the migration of American eels and got two papers published recently in the Nature Communications and ICES Journal of Marine Science.

PhD student Yi Sui studied the dispersion and hydrodynamic connectivity of surface waters on the Scotian Shelf using a numerical model. Yi presented his results at the 49th CMOS Congress in Whistler in June 2015 and the MEOPAR workhop in Vancouver in August 2015.

Milestone table of activities and publications with planned submission dates:

Jan-March, 2016: Dr. Kyoko Ohashi will continue to analyze model results for the simulated movement of Atlantic salmon post-smolts in the northern Gulf of St. Lawrence. Kyoko will also work on the draft of a new manuscript on the effect of the physical oceanographic environment on the movement of Atlantic salmon post-smolts in the Gulf of St. Lawrence. Kyoko is also responsible for running the operational shelf circulation model for the Scotian Shelf.

Jan-March, 2016: Shiliang Shan will work on the revision of the manuscript entitled "Assessing the performance of a multi-nested ocean circulation model using satellite remote sensing and in-situ observations". Shiliang will also work on model results to draft up a new manuscript on the coastal upwelling over the inner Scotian Shelf. Shiliang plans to defend his PhD thesis in June 2016.

c) Significant deviations

No significant deviations from the original objectives for the physical modelling comopnent. Due to the reduced OTN budget, the biogeochemical component led by Katja Fennel was phased out in year 6.

d) Coordination and integration

My research team worked very closely with the ocean observation team led by Dave Hebert and Tetjana Ross (project 4.2) in analyzing observational data along the Halifax line and also using the observational data for assessing the model performance. We also worked very closely with the team for project 4.5 led by Julian Dodson, Martin Castonguay and Melanie Beguer in examining the effect of physical condditions on the migration of American eels. We helped the research team (project 4.6) led by Mike Stokesbury, Michael Dadswell, and Mattew Litvak determine the winter aggregation area of adult Atlantic Sturgeon in the Bay of Fundy.

e) Scientific and/or engineering significance

Reconstrction of the 3D circulation and hydrography over the eastern Canadian shelf is important for various scientific research work including better understadning of circulation variability over the region and the study of the effect of physical conditions on the migration of marine animals.

The numerical circulation model and particle-tracking model developed by this project are very useful tools for many practical applications. They can be used to simulate the movement of passive objects, such as nutrients, buoys, or planktonic marine animals, and can also be programmed to include active swimming behaviours in order to simulate the movement of nektonic marine animals.

The other important scientific findings made by my research team inlcude (a) identification of key processes affecting migration of American eels and Atlantic salmon post-smolt in the Gulf of St. Lawrence and (b) determination of the potential winter aggregation area of adult Atlantic sturgeon in the Bay of Fundy.

f) Significance of research to the community/public

Our research results provide the general public with information about the migration of American eels in the St. Lawrence Estuary, on the Gulf of St. Lawrence and over the northwest Atlantic Ocean. Our results of general circulation and associated variability are also useful for better management of natural resource over the study regions.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Jinyu Sheng, Kyoko Ohashi and Shiliang Shan attended the 3rd International Conference on Fish Telemetry held in Halifax in July 2015.

Shiliang Shan and Yi Sui attended the 49th CMOS Congress held in Whistler in June 2015.

Jinyu Sheng, Kyoko Ohashi, Shiliang Shan and Yi Sui attended the MEOPAR workhop held in Vancouver in August 2015.

My research team has a close collaboration with the PIs and HQP on the American Eel project (project 4.5), including Dr. Julian Dodson, Dr. Martin Castonguay and Dr. Melanie Beguer.

My research team worked closely with the team (project 4.6) led by Dr. Mike Stokesbury, Dr. Michael Dadswell, and Dr. Matt Litvak on the movement of satellite archival tags due to ocean currents between the time they become detached from Atlantic sturgeons and the time they are detected by satellite.

The research team also worked closely with the observation team (project 4.2) led by Dave Hebert and Tetjana Ross.

b) Interaction/Outreach to Broader Community

Interaction and outreach to the broader community occurred through conference and meeting presentations, targeted visits and participation of the PIs in working groups and scientific steering committees. In addition, there were several meetings with DFO scientists (Youyu Lu, Yongsheng Wu, Charles Hannah) and also with international sccientists in China and United Kingdom.

9. Dissemination of information and results

a) Refereed journal articles (4 total) – accepted/published

Ohashi, K., and J. Sheng (2015) Investigating the effect of the physical environment and swimming behaviours on the movement of particles in the Gulf of St. Lawrence using an individual-based numerical model, Atmosphere-Ocean. Doi: 10.1080/07055900.2015.1090390

Urrego-Blanco, J., J. Sheng, and F. Dupont (2015) Assessing the performance of one-way and two-way nesting techniques for the shelf circulation modelling system of the eastern Canadian shelf, Ocean Modelling (in press).

Béguer, M., S. Shan, K. R. Thompson, M. Castonguay, J. Sheng, and J. J. Dodson, 2015. Exploring the role of the physical marine environment on silver eel migration using a biophysical Particle-tracking Model, ICES Journal of Marine Science. http://icesjms.oxfordjournals.org/content/early/2015/10/10/icesjms.fsv169.full

Béguer, M., M. Castonguay, S. Shan, J. Benchetrit, and J. J. Dodson, 2015. Direct Observations of American Eels Migrating Across the Continental Shelf to the Sargasso Sea, Nature Communications, 2015,6:8705. http://dx.doi.org/10.1038/ncomms9705

b) Refereed journal articles (2 total) – submitted

Dever, M., D. Hebert, B.J.W. Greenan, J. Sheng, and P.C. Smith. Hydrography and coastal circulation along the Halifax Line and the connections with the Gulf of St. Lawrenc. Atmosphere-Ocean.

Chang, Y-L, J. Sheng, K. Ohashi, M. Béguer-Pon, and, Y. Miyazawa. Impacts of interannual ocean circulation variability on Japanese eel larval migration in the western North Pacific Ocean, Public Library of Science (PLOS).

d) Conference presentations (5 total) – contributed

Ohashi, K., and J. Sheng, Simulation of Atlantic salmon post-smolt movement in the Gulf of St. Lawrence, 3rd International Conference on Fish Telemetry, Halifax, July, 2015.

Shan, S., and J. Sheng, A Modelling study of coastal upwelling on the Scotian Shelf, 49th Annual CMOS Congress, Whistler, June, 2015.

Sui, Y., and J. Sheng, Numerical Study of Circulation, Dispersion and Hydrodynamic Connectivity over the Scotian Shelf, 49th Annual CMOS Congress, Whistler, June, 2015

Shan, S., and J. Sheng, A Modelling study of coastal upwelling on the Scotian Shelf, Conference of Dalhousie Oceanography Graduate Students, Halifax, March, 2015.

Sui, Y., and J. Sheng, K. Ohashi, Y. Wu, and S. Shan, Dispersion and hydrodynamic connectivity over the Scotian Shelf, a numerical investigation using a nested-grid ocean circulation model, Conference of Dalhousie Oceanography Graduate Students, Halifax, March, 2015.

11. Collaborations with industrial and government partners

b) Contributions

Name of supporting organization: **Lloyd's Register Foundation**	**Year 6** (2015)
Cash contributions to direct costs of research	23,000
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	yes

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.2

2. Project Title: Ocean observation component: fixed and glider-based observations of physical, biological and chemical properties along the Halifax Line (HL) and in rich feeding habitats such as the Gully Marine Protected Area and the Roseway Basin Right Whale Critical Habitat

3. Project Leaders: Dave Hebert (DFO-Bedford Inst, Dalhousie U), Tetjana Ross (Dalhousie U)

Other OTN Canada participants: K. Fennel, J. Sheng, S. Iverson, D. Bowen
Collaborators: Peter Smith (DFO-Bedford Inst, Dalhousie U), Blair Greenan (DFO-Bedford Inst, Dalhousie U), John Kocik (NOAA, USA)

4. Public summary of report

The OTN Observing Component collects a wide array of physical, biological and chemical observations, primarily along the Halifax Line (HL), which serves as the test bed for OTN research in the Atlantic Arena. Analysis of physical data from several bottom moorings containing acoustic Doppler current profilers (ADCPs) that provide measurements of the currents throughout the water column and conductivity-temperature-depth (CTD) sensors near the HL dating back to April 2008 as well as ocean glider data dating back to 2011 continued, resulting in one HQP submitted publication and several conference and workshop presentations. Close collaboration with the OTN Modelling Component (Catherine Brennan and Shilang Shan), researchers tagging Atlantic salmon (John Kocik and Carrie Byron) and the researchers in the MEOPAR Whales Habitat and Listening Experiment (Chris Taggart, Kim Davies and Mark Baumgartner), who are using OTN ocean glider data to assess endangered North Atlantic right whale habitat, continued. Dalhousie's Marine Observations Support Team (MOST) sustained an effective program of ocean glider operations, sampling the ocean interior of the Scotian Shelf xxx glider days during the reporting period, while successfully integrating new sensors (such as the passive acoustic whale detection device, D-MON) and establishing the expertise to deploy and pilot a new surface glider. In addition to the standard sampling along HL the glider team participated for the third year in Gliderpalooza, an international program to sample the eastern seaboard of the United States and Canada, with 19 participating institutions launching 25 missions. All the ocean glider data is shared through web-based data presentations and regular interaction between network members who supply and use the data.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Mathieu Dever	PhD	100	100	Jan 2011	Dec 2016
Research Topic: Dynamics of the Nova Scotia Current and its Relationship with Atlantic Salmon Migration Patterns over the Inner Scotian Shelf.					
Hansen Johnson	PhD	25	0	Jan 2015	Jan 2020
Research Topic: Passive acoustics from gliders – real-time detection of baleen whales.					

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Matt Beck	MSc	100	0	Sep 2010	Jan 2016
Research Topic: A multiparameter approach for estimating chlorophyll a from ocean gliders.					
Gennavieve Ruckdeschel	MSc	30	0	Jun 2014	Dec 2016
Research Topic: Right whale habitat: distribution and dynamics of copepod species in Roseway Basin.					
Cailin Burmaster	BSc	15	0	Jan 2015	May 2015
Research Topic: Class Project: Use of remotely measured spectral irradiance in order to examine light attenuation with offshore distance.					
Brad Covey	RA	60	0	Jun 2014	NA
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Sue L'Orsa	RA	50	0	May 2014	NA
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Cailin Burmaster	Co-op	50	0	Sept 2014	Dec 2014
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Benjamin King	Co-op	50	0	Jan 2015	Apr 2015
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Denays Lamezon	Co-op	50	0	Apr 2015	Aug 2015
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Kat Fupsova	Research Asst	50	0	Jul 2015	Mar 2016
Research Topic: Ecosystem monitoring on the Scotian Shelf.					

b) Role, activities, and opportunities for training

Ocean observation requires highly trained personnel. Long-term staff are essential for the success of the program but cannot be listed in the Section 5(a) and will not be discussed here. Mathieu Dever is a PhD student fully supported by OTN. His role is to process all physical oceanographic observations collected as part project number 4.2, and investigate the dynamics and forcing mechanisms involved in the Nova Scotia Current. Through collaborative work with John Kocik, his role is also to investigate a possible relationship between coastal conditions and migratory behaviour of Atlantic Salmon. Gennavieve Ruckdeschel's MSc thesis will focus on using the echosounder data from the gliders to examine the distribution and dynamics of copepods in Roseway Basin. Matt Beck has just submitted his MSc thesis, which developed new estimates of chlorophyll from glider measurements. This involves extensive skill in programming and in the application of hydrological optics. Brad Covey is our Information Technology specialist. He creates and maintains databases, programs missions for the gliders, maintains computer hardware, and maintains the OTN glider web presence. Sue L'Orsa's primary role is glider preparation, maintenance and deployment. Both Brad and Sue have been trained in house and will soon travel to Webb for formal training. Glider operations, data management and validation sample processing requires extra hands. Our group regularly hires co-op students, such as Cailin Burmaster, Benjamin King and Denays Lamezon to participate in our varied activities, giving them valuable training and skills for the future. Kat Fupsova is working in a similar capacity, but for a longer time so has been hired as a research assistant. Cailin Burmaster's experience with the gliders inspired her to do a glider-data based major project for one of her classes this spring.

6. Progress towards objectives/milestones

a) Overall objectives

One of the major questions framed by OTN-Canada is how oceanographic and environmental features affect animal habitat use, movement and migrations. The ocean observation component collects a wide array of physical, biological and chemical data along the Halifax Line and in Roseway Basin, a critical feeding area for the northern right whale, as well as other areas of the Scotian Shelf. Key ocean processes can be described and that information used to validate models of the ecosystem.

b) Progress

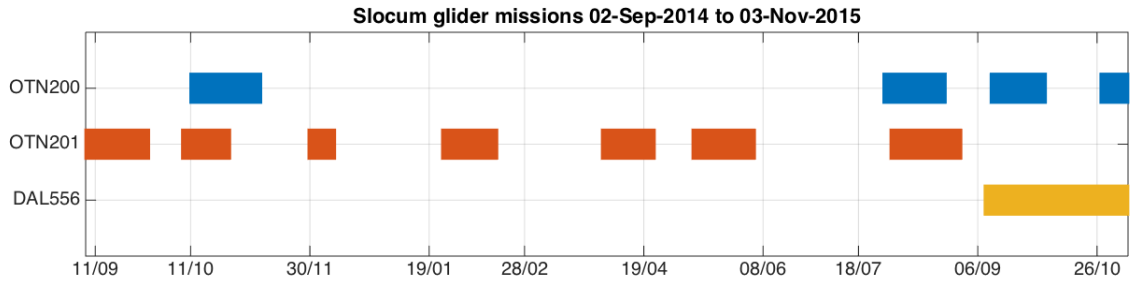

Figure 1. Gantt chart of glider missions for the reporting period. OTN200 and OTN201 are the two G2 slocum gliders owned and operated by OTN. DAL556 is the nnew glider, jointly owned by MEOPAR and OTN and operated by the glider group.

Water mass properties were measured systematically along the Halifax Line, and sporadically in Roseway Basin, using Webb slocum gliders. The two OTN gliders and the new DAL556 glider were in the water for 291 days and flew a combined distance of just over 6150 km, collecting over 15 million data points along the way. Figure 1 is a Gantt chart of deployments for the reporting period and shows the time periods when the gliders were active. Figure 2 is heat map of the glider satellite connections showing the locations of the missions.

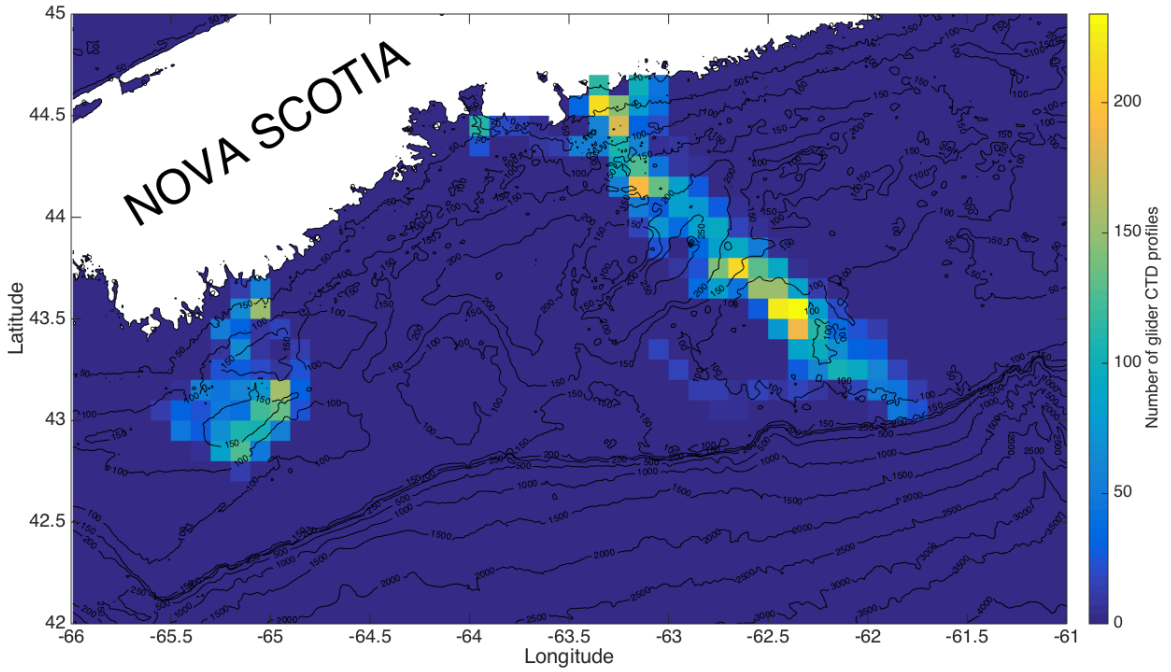

Figure 2. Heat map of glider satellite connections for the reporting period.

These data have been analysed and processed data provided to the OTN modelling group for use in model validation. The data have further been used to develop a better understanding of the dynamics over the Scotian Shelf, and more particularly along the Halifax Line and to link these oceanographic conditions to fish migration pattern and migratory behaviour. The echosounder, which started collecting data in the fall of 2014, have been developed from the raw data shown in last year's report into a data product that can be interpreted in terms of zooplankton abundance (Figure 3).

As reported last time, OTN was invited to participate in an international collaboration ('Gliderpalooza') to enhance ecosystem monitoring on the eastern seaboard of the United States and Canada. Growing out of the MARACOOS and OTN stated science priorities of developing the basis for ecosystem-based management, the success of Gliderpalooza 2013 led to an expanded version for 2014, with ~34 gliders deployed by 17 institutions stretching from the Gulf of Mexico to the Labrador Sea. Gliderpalooza continued in 2015, albeit with less fanfare, but with 21 gliders performing 25 deployments from 19 institutions. For this effort OTN deployed two gliders in September 2015, one in Roseway Basin and the other on the Halifax Line. Data from all institutions is coordinated through MARACOOS and publicly available.

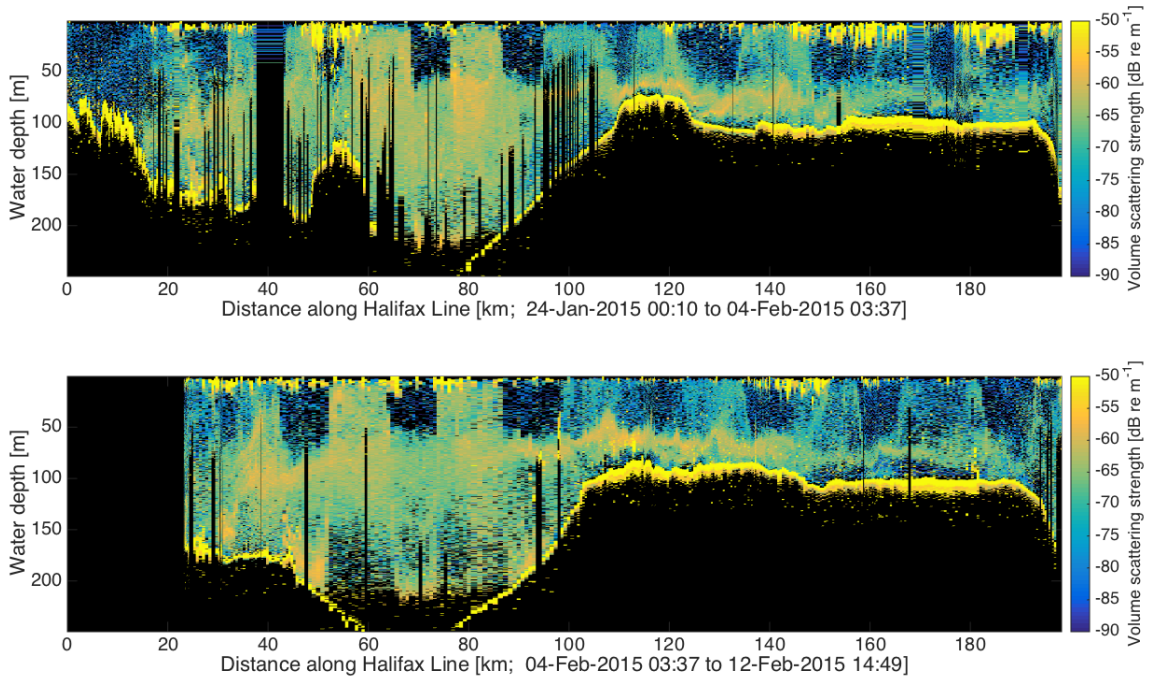

Figure 3. Volume scattering strength from the 300 kHz echosounder equipped OTN glider is a proxy for abundance of zooplankton in the water column. Note how strong scattering is observed periodically in the upper fifty meters. This is because of the diel vertical migration of some zooplankton species (i.e. the high scattering occurs in the upper 50 during the dark hours).

In collaboration with the MEOPAR WHaLE project, we have successfully equipped one of the OTN gliders and a new refurbished glider with DMON (Digital acoustic MONitoring) devices that can detect and report whale calls in near-real time (e.g. Figure 4). The DMON-equipped gliders have now surveyed over 2000 km of the Scotian Shelf. This new technology now allows the tracking of critically endangered species of whale, such as North Atlantic right whales, that cannot be tagged with traditional tags—finally filling a gap in the range of species that can be tracked by OTN.

Beyond the mission to offload bottom-mounted acoustic receivers, the wave glider was deployed on two other missions in support of OTN and provincial agencies. The wave glider was deployed in December 2014 off Cape Breton to track tagged eels. Unfortunately the short days and low sunlight terminated that effort before its time. In June 2015 the wave glider was also deployed off Cape Breton and followed a radiator pattern looking for snow crabs tagged by AMEC as part of a study by Emera to assess the potential impacts of the power link between Nova Scotia and Newfoundland.

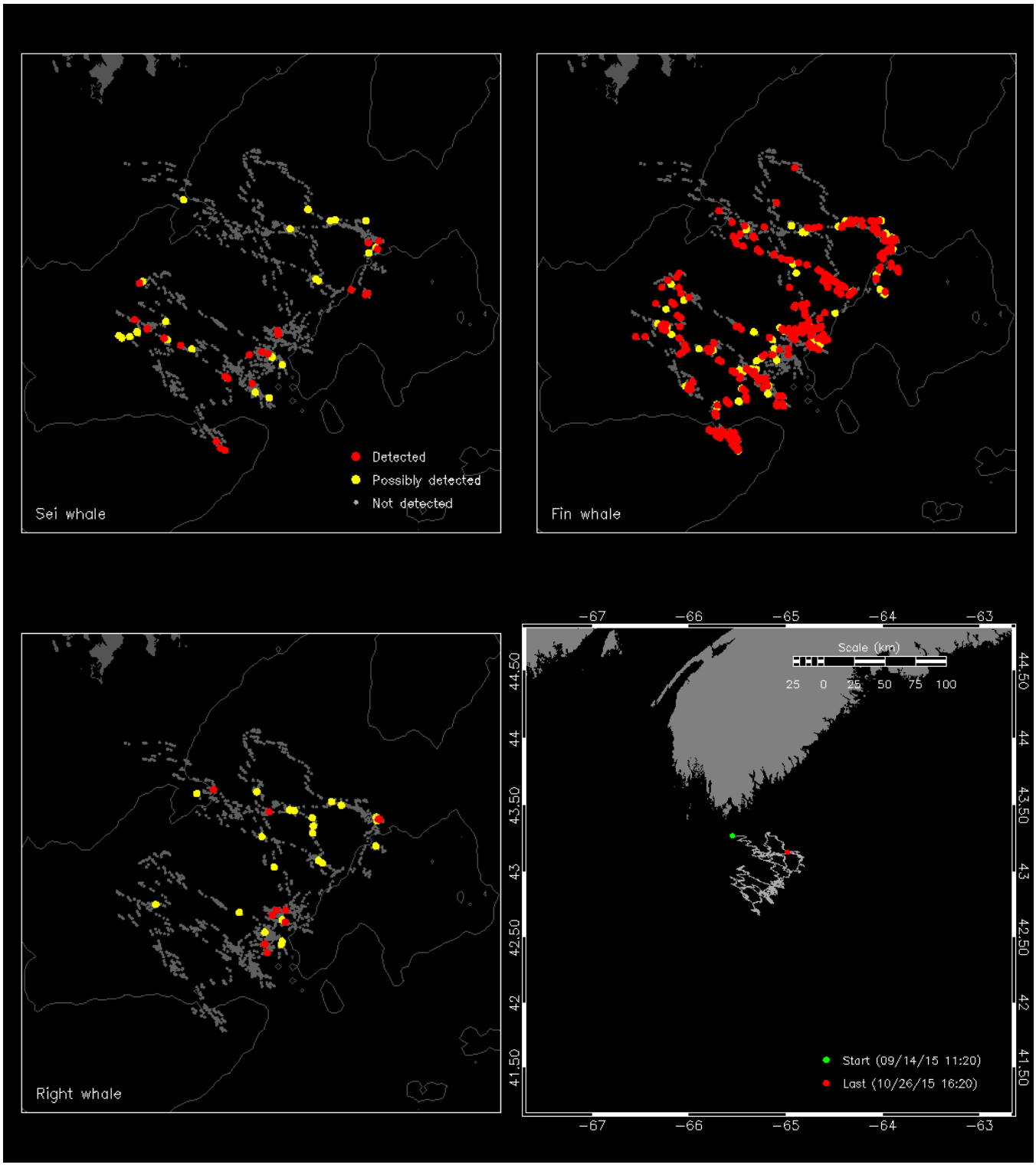

Figure 4. Map of Fall 2015 deployment of the DMON-equipped glider in Roseway Basin on the Scotian Shelf, showing the near-realtime detections of 3 whale species.

Milestone table for HQP activities/output:

HQP	Activity	Dec	Jan	Feb	Spr	Sum	Fall
Dever	Guest speaker at University of Maine, school of Marine Sciences	X					
Beck	MSc thesis defence: "Defining a multi-parameter optics-based approach for estimating chlorophyll a concentration using ocean gliders"		X				
Dever	Seminar at Bedford Institute of Oceanography		X				
Ruckdeschel	Presentation of thesis project as part of HOSST/TOSST seminar series		X				
Beck, Dever	Ross presenting poster: "The physical context of seasonal and inter-annual variability in phytoplankton across the Scotian Shelf: Insights from profiling gliders"at Ocean Sciences Meeting, Dever and Beck are co-authors			X			
Dever	Submission of a manuscript to Marine and Coastal Fisheries entitled: "Linkage between Coastal Conditions, Detection Patterns and Migratory Behavior of Atlantic Salmon Postsmolts (Salmo salar) Along the Halifax Line" (M. Dever, J. Kocik, D. Hebert, J. Zydlewski, J. Hawkes, D. Stich)			X			
Dever	Oral presentation at Ocean Science Meeting in New-Orleans: "Characterization of the Nova Scotia coastally-trapped Current and monitoring of the associated density front using underwater gliders."			X			
Dever	Poster presentation at Ocean Science Meeting in New-Orleans: "Linkage between Coastal Conditions, Detection Patterns and Migratory Behavior of Atlantic Salmon Postsmolts (Salmo salar) Along the Halifax Line"			X			
Ruckdeschel	Submission of MSc thesis proposal			X			
Ruckdeschel	Poster presentation at Ocean Science Meeting in New-Orleans: "How Do Density Fronts Interact with Zooplankton Distributions to Create Baleen Whale Prey-Fields in Roseway Basin?"			X			
Beck, Dever	Ross submitting manuscript to Journal of Marine Systems: "Blooms and subsurface phytoplankton layers on the Scotian Shelf: Insights from profiling gliders", Dever and Beck are co-authors				X		
Dever	Submission of a manuscript to Journal of geophysical research entitled: "Extended method to characterize coastally-trapped, buoyancy-driven currents: A comparison between the Nova Scotia Current and the Norwegian Coastal Current" (M. Dever, Ø. Skageseth, K. Drinkwater and D. Hebert)				X		
Ruckdeschel	Research visit to GEOMAR (Kiel, Germany) to				X		

	discuss glider data analysis with Dr. Johannes Karstensen						
Beck	Submission of a manuscript: "Defining a multi-parameter optics-based approach for estimating chlorophyll a concentration using ocean gliders"					X	
Dever	PhD Thesis defence: "Dynamics of the Nova Scotia Current and its relationship with Atlantic salmon migration patterns over the Scotian Shelf"					X	
Ruckdeschel	MSc Thesis defence: "Biophysical interactions between zooplankton and fronts in Roseway Basin" (will lead to at least one publication in 2017)						X

c) Significant deviations

No significant deviations.

d) Coordination and integration

Coordination between the project's co-investigators and collaborators was coordinated through biweekly information and planning meetings around glider operations as well as more in-depth discussions during face-to-face meetings at meetings like the OTN symposium.

e) Scientific and/or engineering significance

Results from Mathieu's work, analysing fixed and OTN ocean glider-based physical observations along the Halifax Line, allows a better understanding of the forces involved in coastal circulation over the Scotian Shelf and buoyancy-driven, coastally trapped current in general. It provides the oceanographic base on which studies of migratory behaviour can rely on. It also provides both datasets for model validation and new insights in order to assess model performance.

The results from the DMON and echosounder observations are still quite new but they are being used to locate the feeding and occupancy hot-spots for baleen whales on the Scotian Shelf. For example, Roseway Basin is a puzzle; right whales often use it throughout the late-summer, so much so that it has been protected, but some years – and apparently 2014 is one – they simply abandon it, and no one knows where they go. We now have two years of data, containing the physical, chemical and biological variables necessary to describe whale habitat, containing and abandonment year and a 'normal' year, which can be compared to determine the cause.

The wave glider proved itself by uploading >180 bottom-mounted receivers along the Halifax Line representing the bulk of VR4s deployed on the Line. Being able to upload receivers using a robot will save OTN considerable money and time in the future.

Collaboration between the glider group and industry has resulted in advancements in passive acoustic monitoring of the environment from autonomous vehicles. Three different companies (Geospectrum Technologies, Ocean Sonics, Turbulent Research) have all developed systems that can be deployed on the wave glider and used to listen for marine mammals. It is expected that these commercially available products can be sold internationally.

f) Significance of research to the community/public

OTN's ocean observation component is a source of much interest to the general public – as evidenced by the diverse visitors hosted by the glider group as well as the amount of media coverage of glider activities (see below for details). The fishing community is very interested in the data we are collecting and we are working on creating useful data products to share with fishermen on a regular basis in order to increase our benefit to them.

Real-time data from the gliders are transmitted as part of the Global Telecommunication System. The GTS data is available to any subscribing agency, such as the WMO, and is used in activities such as weather forecasts and ocean modelling.

7. Difficulties encountered

☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)
☒ Other (specify): Space limitations, resource limitations

We continue to have problems with the VM4 towed behind the wave glider and used to offload bottom-mounted VR4s. While the unit nominally works and is capable of offloading the data the interface is clunky and certain key commands, such as abort, often do not work. Attempts to rectify this problem with Liquid Robotics and VEMCO have proven fruitless.

At the end of mission 45 one of our slocum gliders was retrieved by a fisherman and the echo sounder damage slightly.

Piloting services provided by Liquid Robotics are not as conscientious as they could be, often leaving the wave glider in an undesired state. OTN / MEOPAR now pilots the wave glider for 12 out of 24h but this is not a long-term solution without an increase in staff members.

The glider group has no dedicated space and is currently at the whim of BIO and CERC-OST. We are also split between BIO and Dalhousie University. Having dedicated space in one building both increase productivity and foster cohesiveness. Finally, the success of the glider group and the number of projects currently supported means that personnel are stretched thin, and some projects are not started in a timely fashion.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Dalhousie Glider workshop: involving OTN and MEOPAR users and potential users of the OTN gliders sharing knowledge, methods and data. Halifax, April 2015.

This workshop triggered further meetings with interested users which has (so far) led to one new manuscript in preparation: "The Physical Context of Seasonal and Inter-Annual Variability in Phytoplankton across the Scotian Shelf: Insights from Profiling Gliders" (Tetjana Ross, Dr. Susanne Craig, Mathieu Dever and Matthew Beck).

Collaboration between Mathieu Dever and Shiliang Shan aimed at validating a nested-model developed by Jinyu Sheng's group. Several valuable data sources processed by Mathieu Dever were used (ADCP, bottom conditions, glider transects) and successfully helped making the Shiliang's model more reliable.

The MEOPAR funded WHaLE projects depends on deployment of autonomous vehicles by the glider group to achieve their goal of real-time monitoring of marine mammals.

b) Interaction/Outreach to Broader Community

The on-going collaboration between Mathieu Dever and U.S. scientists John Kocik, Joseph Zydlewski and Dan Stich aiming at linking Atlantic salmon smolts migration patterns to hydrographic conditions is reaching fruition; with two manuscripts in preparation to disseminate the results.

The glider group is an active participant in Ocean Gliders Canada, resulting in close collaboration with Dr. Stephanie Waterman of UBC. Dr. Waterman sent her glider to Dalhousie University in early 2015 to be inspected and prepared for deployment by the Dalhousie team.

OTN is a regular participant in Glidarpalooza, an international collaboration of academia, government and private industry in which gliders are deployed along the eastern seaboard of the North America as well as the Gulf of Mexico during late summer and early fall. Data from the deployments are shared amongst the groups with an aim to improve ocean model predictions. Another goal of Gliderpalooza is to improve response times of varied glider groups during extreme events.

9. Dissemination of information and results

b) *Refereed journal articles (1 total) – submitted*

M. Dever, D. Hebert, B.J.W. Greenan, J. Sheng and P.C. Smith: Hydrography and coastal circulation along the Halifax Line and the connections with the Gulf of St. Lawrence. Submitted to *Atmosphere-Ocean*

(***Note*** this is the same article as was listed in 2014. Originally, Mathieu was planning to write a single paper with both physics and salmon tracking. His co-authors suggested that it should be two papers. However, in last year's report, the wrong title was given. It should have been: M. Dever, D. Hebert, B.J.W. Greenan, J. Sheng and P.C. Smith: Hydrography and coastal circulation along the Halifax Line and the connections with the Gulf of St. Lawrence. Submitted to Atmosphere-Ocean. It has been a long review process (over 1 year) for this special issue of A-O. We are expecting an editor's decision on the revised manuscript shortly. We expect it to be accepted since we have addressed all of the items that one of the reviewers had. The other reviewer had said it was acceptable.)

c) Conference presentations (1 total) – invited

Davis, R., A. Comeau, S. L'Orsa, B. Covey. Glider outreach workshop. ICFT, Halifax, July 2015.

d) Conference presentations (2 total) – contributed

T. Ross, K. Davies, C. Taggart, A. Comeau, R. Davis, M. Baumgartner, B. Martin, and G. Ruckdeschel. Surveying right whale habitats using glider-mounted sonar. Canadian Meteorological and Oceanographic Congress, Whistler, June 2015.

G. Ruckdeschel. The case of the missing copepod: Transport and retention mechanisms for copepods in Roseway Basin using an echosounder-equipped ocean glider. Conference-Dalhousie Oceanography Graduate Students. Halifax, March 2015.

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

In collaboration with the MEOPAR WHaLE project, the OTN gliders were in featured in many media outlets:

Television:	1	Global National News	globalnews.ca/news/2164511/deep-diving-drones-search-for-endangered-right-whales-off-east-coast/
	2	CBC Land and Sea documentary	Filmed in Aug 2015, expected air date in autumn 2015
	3	CBC News	www.cbc.ca/m/news/canada/nova-scotia/proposed-right-whale-protected-habitat-expansion-pleases-kim-davies-1.2968530
Radio:	4 - 7	CBC Mainstreet; Halifax News 957; CBC information morning Saint John, Moncton & Fredericton	www.cbc.ca/player/Radio/Local+Shows/Maritimes/ID/2672180479 www.cbc.ca/player/News/Canada/NB/Audio/ID/2672260451/
Press:	8	Chronicle Herald	http://thechronicleherald.ca/novascotia/1312707-right-whales-off-cape-breton-going-the-wrong-way-for-shipping-fishing
	9	Progress Media	http://www.progressmedia.ca/article/2015/08/uncharted-territory
	10	Canadian Press	www.cbc.ca/news/canada/nova-scotia/technology-used-in-hunt-of-a-different-kind-for-north-atlantic-right-whales-1.3159665
	11	Halifax Media Co-op	halifax.mediacoop.ca/story/all-song/33239

b) Invited or contributed open-to-public presentation/contribution

The glider group participated in Doors Open Halifax 2015 (6-7 June 2015), in which >1400 people toured the Steele Ocean Science Building.

c) Invited or contributed presentation/contribution at a workshop

D. Duffus, C. Fox, R. Burnham and K. Hujdic. WHaLE on the West Coast. MEOPAR Annual Scientific Meeting, Vancouver, June 2015.

H. Johnson, M. Baumgartner, K. Davies and C. Taggart. Real-time reporting of baleen whale vocalization. MEOPAR Annual Scientific Meeting, Vancouver, June 2015.

T. Ross and G. Ruckdeschel. Surveying right whale habitats using glider-mounted sonar. MEOPAR Annual Scientific Meeting, Vancouver, June 2015.

f) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, conference proceedings, as well as a contribution to a larger piece of work in any of the former (Note: please provide web links to the reports where possible)

Hebert, D., Pettipas, R., Brickman, D., and Dever, M. 2014. Meteorological, Sea Ice and Physical Oceanographic Conditions on the Scotian Shelf and in the Gulf of Maine during 2013. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/070. v + 40 p. (http://www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2014/2014_070-eng.html)

Hebert, D., Pettipas, R., Brickman, D., and Dever, M. 2015. Meteorological, Sea Ice and Physical Oceanographic Conditions on the Scotian Shelf and in the Gulf of Maine during 2014. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/040. v + 49 p. (In press.)

g) Data deposition to an agency/database (e.g., MEDS, GenBank, OBIS)

The real-time data from the gliders are regularly sent to the Global Telecommunication System to be available for weather forecasting for agencies such as the WMO.

l) Internet publishing, portal, blog, electronic publications

During Gliderpalooza the glider group makes occasional blog entries in the MARACOOS blog section.

m) Anything else that isn't a primary publication that has you communicating with others

The glider conducted multiple tours in the last reporting year, a great opportunity to speak directly to interested parties. Below is a list of tours given.

17 Oct 2014 President of Nanjing University and entourage

13 Nov 2014 Robert Chisholm, MP

8 Mar 2015 Third grade class from Le Marchant - St Thomas School

7 May 2015 CCECE participants

4 Aug 2015 Delegation from State Oceanic Administration of China

22 Aug 2015 Open ship aboard R/V Merian

28 Sep 2015 Bruce Heyman, US ambassador to Canada

For the third year in a row the glider group has made presentations to the ocean themed camp conducted by SuperNova (6 Jul, 20 Jul, 17 Aug).

n) Leveraging your research/funds in order to make a new contribution to another initiative

The glider group is able to support several projects by leveraging funding from various sources, including OTN Canada. Support for the lead glider tech makes contributions to MEOPAR and other glider groups possible.

11. Collaborations with industrial and government partners

a) Partners

The glider group works closely with the Bedford Institute of Oceanography, providing glider data directly to DFO researchers. Space provided by BIO is invaluable to the glider group as no suitable space was ever designated at Dalhousie University. Discussions with DRDC and DND have been fruitful, with DRDC agreeing to lend two slocum gliders to Dalhousie that are capable of passive acoustic monitoring while DND has offered logistical support in return for aid in determining marine mammal locations in real time. Recently the glider group has begun to work with local companies (Geospectrum Technologies, Ocean Sonics, Turbulent Research) to facilitate the integration of passive acoustic hydrophones in autonomous vehicles.

b) Contributions

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	2500
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	15200
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **CERC**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	9600
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **MEOPAR**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	65519.88
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	No

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.3

2. Project Title: Accelerometry techniques and applications

3. Project Leaders: Christopher Taggart (Dalhousie U)

Other OTN Canada participants: K. Fennel, J. Sheng, M. Litvak, M. Stokesbury, S. Iverson, D. Bowen, G. Crossin, I. Fleming, A. Fisk, S. Hinch, S. Ferguson
Collaborators: Dale Webber (Vemco)

4. Public summary of report

The accelerometry research has led to a significantly enhanced accelerometer and inertial navigator tag designs. After developing a market-ready inertial tag that is commercialized through Broell's spin-off company Maritime bioLoggers, there was high commerical potential and an NRC-CNRC ARP grant was secured. Efforts made using the technology have resulted in an empirical model that relates acceleration to fish size (<20% uncertainty in size prediction) in two species of fish, which has the potential for incorporation into on-board processing to eventually measure size-at-age (growth rate) in fish. The tags have also been used to investigate how shortnose sturgeon change their behavioural and activity patterns in relation to environmental variations (temperature, depth, ambient light, tidal velocity) in the wild. Post-tagging effects on behaviour and energy expenditure is also being addressed using fish in captivity (Atlantic Cod) and in the wild (sturgeon) by measuring frequency and intensity of aberrant behaviour related to various tag loads. In collaboration with the International Pacific Halibut commission, tags have also been deployed on Pacific Halibut in Alaska to determine base levels of movement and behaviour during the summer months in 2015. In collaboration with the Atlantic Arena, 30 inertial and accelerometer tags have been deployed on 15 seals to measure activity and prey-capture events. One manuscript based on the research has been published, two additional manuscripts have been submitted and are in review and another is nearing completion for submission in 2015.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Franziska Broell	PhD	100	80	May 2010	May 2016
Research Topic: Accelerometry, the key to measuring size-at-age and activity in fish					
Celene Burnell	research assistant	10	0	summer 2015	summer 2015
Research Topic: Measuring abnormal rotational movements in free-swimming fish with accelerometers					
T Reyno, Z Burns-Grady, J Skaalum, G Winsor	BSc	10	100% lab equipment	May 2014	Apr 2015
Research Topic: Determination of accelerometer tag drag (Engineering design project)					

b) Role, activities, and opportunities for training

F Broell, PhD candidate supported by OTN in 2011-2015 and A Bezanson (PhD candidate, Biomedical Engineering), have developed high-frequency accelerometer tags (MBLog MK1). The tag designs led to a commercial spin-off through Maritime bioLoggers, a new company spearheaded by Broell and Bezanson. Broell and Bezanson are currently developing the next generation long duration inertial sensor with an NRC ARP grant facilitated by NRC-CNRC and awarded in 2015. Broell has also initiated a collaborative effort between OTN and the International Pacific Halibut Commision (T. Loher) and University of Alaska (A. Seitz, J. Nielsen). The collaborative project, led by Broell, included a lab-based study (Newport Aquarium, Oregon, USA) in conjuction with a field deployment of Pacific halibut to determine movement and behaivoural routine of these commercially valuable fish during the summer months using the newly developed MBlog MK1.

6. Progress towards objectives/milestones

a) Overall objectives

Our overall goal is to use high-resolution accelerometers and temperature-depth recording PSAT tags to: a) obtain time, space, state, and rate data and inferred behaviour for a variety of species and b) validate that acceleration metrics derived across a size range of fish species are a function of size; a demonstration, that in the future, archival tags can be used to estimate growth rate in the wild and how much of that rate is explained by temperature (Neuheimer & Taggart 2007) and energy expenditure, and c) address fish movement/distribution and growth in conjunction with ocean models where the tag related parameters (size/growth, temperature, swimming speed, activity, location etc.) constrained by the fish will be incorporated into the model. Our primary focus has been on cod, pollock and sturgeon and most recently Pacific halibut and grey seals through international and OTNC collaborations.

Particular goals include: i) validate that acceleration metrics in a fish are a function of size-at-time; ii) determine key parameters from the acceleration frequency spectrum and/or other relevant statistics that scale with size at age; demonstrate that similar acceleration metrics will provide estimates of activity of marine animals (fish, sea turtles, seals etc.); demonstrate that acceleration metrics will provide in situ estimates of feeding activity and energy budget estimation.

b) Progress

Our main objectives over this past year were to: 1) finalize the empirical model from multiple free-swimming trials (Aquatron pool tank) on various sizes of pollock and sturgeon conducted in 2012 to define acceleration metrics that scale with size, 2) finalize the manuscript on effect on behaviour and stress response to external tagging using accelerometer sensors in captivity (Atlantic cod), 3) analyze data from deployments of shortnose sturgeon in collaboration with M Litvak (Mount Allison) and his team working with conventional V9 acoustic tags to identify sturgeon activity as well as post-tagging behavioural and stress response in the wild, 4) collect data in captivity (Newport Aquarium, USA) and in the wild (Alaska) in collaboration with IPHC and University of Alaska using acceleration and inertial sensors on Pacific halibut to determine baseline behaviour during the summer months and assess the potential to measure size-at-age in this species using the empirical models developed for other species, 5) similar (shorter duration) data are being collected in collaboration with A Fisk and N Hussey (Arctic arena) on Greenland halibut with the aim to contrast behavioural routines and movement amongst the two different species and environment, and 6) deploy accelerometer and inertial sensors on seals in

collaboration with D Lidgard and S Iverson (Dalhousie) and D Bowen (BIO) to measure feeding behaviour, energy expenditure and movement in the wild.

(1) Broell used data from multiple free-swimming trials with pollock (Pollachius virens) and shortnose strugeon (Acipenser brevirostrum) to develop a empirical scaling model between size (weight) and acceleration (Tail Beat Frequency; TBF). This scaling model is similar to established scaling relationships (Sato et al. 2007) based on muscosceletal scaling theory and can predict size-at-time with an uncertainy lower than 20%. This model has the potential to be used to measure size-at-age (growth rate) in the field. A manuscript has been submitted and is currently under review at PLOSone. Maritime bioLoggers is currently developing the hardware to facilitate the incorporation of the relevant software into their accelerometer sensor for on-board processing to deliver estimates of growth rate in tagged fish.

(2) Broell and Burnell used data from free-swimming Atlantic cod trials to investigate stress and behavioural response resulting from external accelerometer tagging through analysing variations in acceleration records that reflect aberrant behaviour. Free-swimming wild Atlantic cod (Gadus morhua) held in a large mesocosm exhibited distinctly aberrant rotational swimming (scouring) when externally tagged with accelerometer data loggers. To quantify the phenomenon, the cod were tagged with two sizes of loggers that measured tri-axial acceleration at 50 Hz. An automated algorithm, based on body angular rotation, was designed to extract the scouring and normal (swimming or gliding) movements from the acceleration signal (98% accuracy, 94% precision). The algorithm also identified the frequency pattern and associated energy expenditure of scouring that was quantified in relation to maximum acceleration and tag load. The per cent time spent scouring was independent of tag load (on average 5%), energy expenditure increased with tag load ($r2 = 0.51$), and fish with large tags spent more energy when scouring than fish with small tags ($p < 0.05$). The information allowed us to determine potential detrimental effects of an external tag on fish behaviour and how the effects may be mitigated by tag size. The algorithm can potentially identify similar rotational movements associated with spawning, courtship, feeding, and parasite-load shedding in the wild. The results infer a more careful interpretation of data derived from external tags and careful consideration of tag-type, -drag, -buoyancy, and -placement, as well as animal buoyancy and species. The research gives insights into not only tagging effects, but also potential relations to ectoparasites and the impact such parasites may have on cod as they are a key species in the North Atlantic ecosystem and provide economical value in commercial fisheries and aquaculture production. The manuscript is currently under review: Journal of Experimental Biology.

(3) In collaboration with M Litvak and A Taylor (MSc) at Mount Allison we successfully deployed pop-up satellite tags (PSAT) from Desert Star Systems that are capable of recording temperature, depth, light levels and the Weelog mini tags in October 2012. Six deployments with six fish of different sizes (83 to 109 cm) were carried out collecting more than 144 hours of high-frequency accelerometer data (50 Hz) and 100 hours of associated temperature, depth and light data (1 Hz). These data are being used to demonstrate how shortnose sturgeon change their behaviour and activity pattern with respect to changes in tidal velocity and other environmental variables. Additionally, the sturgeon display variability among individuals in post-tagging recovery where behaviour ranges from increased activity to prolonged resting. Such variations may make some individuals more vulnerable to the recreational fishery. We have also demonstrated that fish average swimming speed is independent of size and is much lower than reported in the literature (~0.15m/s); potentially a result of tagging stress. These results are providing insights to stress response for fish in a recreational

fishery and may be useful in developing techniques to mitigate catch-and-release effects. A mansucript is in its final stages and will be submitted to Animal Biotelemetry in December 2015.

(4) We collected data in captivity (Newport Aquarium, USA) and the wild (Alaska) in collaboration with IPHC and U. Alaska using acceleration and inertial sensors on Pacifc halibut to determine baseline behaviour during the summer months and to assess the potential to measure size-at-age in this species using the empirical models developed for other species. The 1st phase of the 2-phase project involved a lab-study in Newport Oregon with tagging 12 individuals with a 76 to 107 cm size range. The motivation was to establish the tagging protocol for the field study and secure data to address scaling between swimming parameters and size. The lab study has been completed and the data are yet to be analysed in preparation for a publication.The 2nd phase of the 2-phase project is the field study off the coast of Juneau (Chigagov Island). The tagging of 14 individuals with PSATS and accelerometers off the coast of Juneau using fish in the size range of 80 to 150 cm was completed in August 2015. The motivation is to secure high-resolution (feeding, activity) and low-resolution (migration, diurnal pattern) accelerometry data to quantify behaviour as well as to assess scaling between swimming parameters and size in the field (related to phase-1 lab study). Data will be used to determine halibut activity over the summer months as well as assess the potenetial of measuring size-at-time in halibut using the empirical model established for saithe and shortnose sturgeon. At the same time, similar (shorter duration) data are being collected in collaboration with A Fisk and N Hussey (Arctic arena) on Greenland halibut with the aim to contrast behavioral routines and movement amongst the two different species and environment. Data analyses will be carried out by Broell in 2016. A minimum of 2 primary publications from this projects are expected and should be sumitted sometime in 2016.

(5) A collaboration of D Lidgard and S Iverson (Dalhousie) and Don Bowen (DFO/BIO) with Broell and Maritime bioLoggers is underway to investigate the use of high-frequency accelerometers to measure feeding behaviour in seals tagged on Sable Island (June – December 2015). Head-mounted accelometer tags and back-mounted inertial tagas were attached to 17 male seals to collect data on feeding beaviour and relate these data to the presence of potential prey items; e.g., tagged Atlantic cod (as recorded by seal-mounted VMT recievers). Additionally, two seals are carrying video cameras that will deliver in situ video observations during prey-capture. The video observations will be used to calibrate the accelerometer and interial tags for prey-capture events. The acceleration data can then be used to quantify pre-capture events and attempts over the deployment time as well as fine-scale acivity patterns, energy expenditure and behvaiour. Tags will be retrieved in January 2016. Analyes will be carried out by Broell and Lidgard in 2016. A minimum of 2 primary publications and more likely 4 will derive from this project and should all be submitted some time in 2016.

(6) Two manuscripts are currently under review and one will be submitted to Animal Biotelemetry in Dec. 2015.

a. Broell, F., and Taggart, C.T. (under review). Scaling in free-swimming fish and implications for measuring size-at-time in the wild. PLOSone

b. Broell, F., Burnell, C., and Taggart, C.T. (under review). Measuring abnormal rotational movements in free-swimming fish with accelerometers: implications for quantifying tag- and parasite-load. Journal of Experimental Biology.

c. In prep. Post-catch-and release effect on behaviour in shortnose sturgeon as measured with high-frequency accelerometer and pop-up satellite tags. Target: Animal Biotelemetry

Four to six manuscripts will be developed based on the Halibut and seal tag data ((4) and (5) above)

c) Significant deviations

We expected to publish a MS entitled: Tag drag, lift and load as a function of fish size and tag size and design based on a project conducted in collaboration with the Mechanical Engineering Department at Dalhousie (4th Engineering Project) and Maritime bioLoggers. However, the outcome of the student-led project was not suitable for publication since the deliverables set for the project team were not met, and at some expense. We were not pleased with the project team performance.

d) Coordination and integration

Franziska Broell, in concert with Taggart, has taken the lead in virtually all of our collaborations within the OTN Atlantic Area, including IPHC, University of Alaska, Litvak et al. (Mount Allison), Maritime bioLoggers in Halifax, Damian Lidgard et al. (Dalhousie) and A Fisk. These have been achieved through scheduled one-on-one and team meetings as well as regular Skype meetings and email coordination and in-the-field operations. Especially the attendance of Broell at international conferences was key for coordination of collaborations, both old and new: For example, the collaboration between IPHC and Universiy of Alaska was initated by Broell during the 5th Biologging Conference, and here attendance was supported by OTN. Collaboration with the Arctic Arena was initated by Broell during the 3rd ICFT (supported by OTN).

e) Scientific and/or engineering significance

To date our work has shown that various metrics derived from remote accelerometer data scales with fish size and thus can be used to remotely estimate fish growth in the wild. Our work also demonstrates significant effect from external tags (including widely used Petersen disk tags) in Atlantic cod, which may have an effect on data obtained in mark-recapture studies. From an engineering perspective, our novel accelerometer tags have been greatly enhanced in terms of size and energy consumption and are now being sold through Maritime bioLoggers including national and international customers. Further research and development for the next generation interial biologging tag is currently underway and will revolve around developing a market-ready inertial senesor with funding support from NRC-ARP.

7. Difficulties encountered

☒ Other (specify): the 4th year engineering team research project did not deliver as was expected

Despite many meetings and timelines and deadlines and reporting schedules, the team was clearly not organised and/or motivated. Oversight on the part of the Engineering leadership could have been somewhat more rigorous.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Subsequent to the 2011 and 2012 OTN symposium meetings we have established formal collaborations that did not exist at the outset of our OTN research. This includes the collaborations with Litvak (Atlantic Arena, Mount Allison), Lidgard (Atlantic Arena, Dalhousie) and Fisk (Arctic Arena,

University of Windsor) We have also established a collaboration between the International Pacific Halibut commission and the University of Alaska. To date these have proven rewarding for all collaborators due to the various synergies and will continue into the future.

The recently funded MEOPAR-WHaLE project (see 10-n below) has allowed for newer and expanded collabortation with the OTN glider programme research. Ross is a co-PI and Hebert a collaborator in the WHaLE research that would not have happened without OTN support and collaboration that will be mutually beneficial to both OTN and MEOPAR.

b) Interaction/Outreach to Broader Community

There has been considerable interaction/outreach via Maritime bioLoggers with approximately 20 different researchers/agencies around the world.

9. Dissemination of information and results

b) Refereed journal articles (2 total) – submitted

Broell, F., and Taggart, C.T. (under review). Scaling in free-swimming fish and implications for measuring size-at-time in the wild. PLOSone

Broell, F., Burnell, C., and Taggart, C.T. (under review). Measuring abnormal rotational movements in free-swimming fish with accelerometers: implications for quantifying tag- and parasite-loadd. Journal of Experimental Biology.

d) Conference presentations (2 total) – contributed

Broell, F., Taggart, C.T. (2015) Scaling in fish swimming and implications for measuing size-at-time in the wild. 3rd International Fish Telemetry Conference

Nielsen, J.K., Broell, F., Loher, T., Rose, C., Drobny, P., Taggart, C.T., & Seitz, A.C. (2015) Characterizing and quantifying activity patterns of fish with accelerometer archival tags: Pacific halibut as a case study. AFS Meeting Alaska

10. Other contributions and deliverables

n) Leveraging your research/funds in order to make a new contribution to another initiative

Maritime bioLoggers, IRAP ARP Project: Advancement of the nextg-generation biologging sensors.

o) A spin-off from the research that provided a new opportunity or new initiative

Martime bioLoggers

p) A new technology, method, protocol, measure, analytical technique, algorithm, operational or numerical model, or predictive tool. Include the validation of any of the former and their practical application

New Technology: Our high-frequency accelerometer and inertial tags represent a new and advanced technology of interest to industry and a number of other researchers who are interested in various practical applications ranging from research, aquaculture to governmental applications. We have further developed statistical and programming procedures for estimating various acceleration metrics that are used to estimate fish size (20% uncertainty) and therefore growth and to detect and identify various activities (feeding, escape, passive movements, tag stress, rotational movement etc.). Maritime bioLoggers aims to incorporate these algorithms into on-board processing of the current technology.

Tag attachment protocol: Litvak and Broell have also developed a new tag attachment technique for ridigt PSAT accelerometer tag mount that delivers acceleration data that can be used to relate to animal behaviour in the wild. This protocol will be published along with the result from the data collection on shortnose sturgoen in the MS outlined above.

q) A proof of concept in relation to any of the above

All of our accelerometer tags have been successfully deployed in the laboratory and in the field. Further development and commercialization through Maritime bioLoggers - especially the decision of an independent examining group (Innovacorp, NRC-CNRC) with experience in business and product development to fund the R&D for further development of the sensor prototype attests to the success of the concept.

r) Baseline measures (e.g. reference for change), empirical relations (e.g. rates and states), or mapping products (e.g. range expansion or contraction) especially if of use to other scientists and the organizations listed above

We have established baseline measures (e.g. reference for change), empirical relationships (e.g. rates and states), and critical sampling frequencies related to aliasing of value to other scientists and the organizations listed above.

11. Collaborations with industrial and government partners

a) Partners

Our technological advancements are now comercially available through Maritime bioLoggers (www.maritimebiologgers.com). Maritime bioLoggers has been a significant contributed for new prototype technology in the collaboration study with seal project (Lidgard et al.) and IPHC collaboration (Halibut project).

Research Partner: IPHC - international Pacific Halibut Commission (Tim Loher, Research Biologist). Location of Study: Alaska, Species: Halibut, Tagging method: Satellite telemetry.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.4

2. Project Title: Overwinter biology, migrations, and carryover effects of Bras d'Or Atlantic salmon populations

3. Project Leaders: Glenn Crossin (Dalhousie U), Bruce Hatcher (Cape Breton U)

Other OTN Canada participants: S. Cooke, S. Hinch, I. Fleming, C. Taggart
Collaborators: Gary Bugden (DFO-BIO), Dave Patterson (DFO – Pacific), Brian Petrie (DFO-BIO), Dale Webber (Vemco), Fred Whoriskey (OTN), Jinyu Sheng (Dalhousie U)

4. Public summary of report

Beginning in November 2014 we began our project by capturing, sampling, and acoustically tagging 21 post-spawning Atlantic salmon kelts from rivers in the Bras d'Or Lakes ecosystem of Cape Breton, Nova Scotia. Roughly half of these fish were collected after wild spawning on the Middle River, and half were wild fish that were captured and spawned in a provinical hatchery as part of a broodstock enhancement program. Our aims were twofold. First was to identify the biological and environmental factors that account for individual variation in the post-spawning behaviour and survival of kelts. Second was to compare difference in physiological condition and migration behaviour between artificially spawned broodstock relative to wild spawned fish. Preliminary results show that post-spawning condition predicts variation in migration timing and survival. Fish in relatively good conditon (e.g. high relative body mass) tended to overwinter in the natal river before migrating to the Bras d'Or Lakes in spring and then onwards to the Atlantic Ocean. Poor condition fish tended to migrate immediately downstream to the Bras d'Or after release, choosing to overwinter there rather than in the river. Although we are awaiting more detection data from our acoustic receiver array, it appears that mortality was high in these poor condition fish, and none have yet been detected migrating to sea. In terms of the broodstock/wild comparison, broodstock fish have higher spost-spawning stress measures (plasma cortisol, lactate), and lower overall survival. Although these results suggest a potential effect of broodstock handling on the behaviour and survival of salmon, greater statistical power is needed. For the upcoming 2015 season beginning in November, we will repeat our 2014 tagging protocol, but will increase our sample size to 40 fish, thereby increasing the power of our comparisons. Continued analyses will also explore variation in habitat use within the Bras d'Or Lakes, and the environmental correlates of residencies.

5. Training of Highly Qualified Personnel

a) <u>HQP and level of support</u>

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Xavier Bordeleau	PhD	100	80	1 Sept 2014	31 Dec 2018
Research Topic: Physiological and environmental correlates of habitat use by adult Atlantic salmon in the Bras d'Or Lakes, Nova Scotia					

b) Role, activities, and opportunities for training

X. Bordeleau entered this project as an MSc student at Dalhousie in Sept 2014. He has since rolled into a PhD program. His role is to lead the field program and all physiological and telemetric analyses. These will form a core part of his doctoral work, which is exploring the importance of kelt life histories to population processes in salmon and trout. This work is based in Cape Breton, Norway, and Kerguelen. Xavier is learning methods for the analysis and interpretation of acoustic telemetry data. Likewise, he is learning fish capture, handling, and surgical techniques, as well as physiological analyses and their interpretation. He has and will continue to present his findings at international conferences, and is currently writing up the first chapter and manuscript of his thesis. He is gaining additional support and training via networking activities with others in the Ocean Tracking Network.

6. Progress towards objectives/milestones

a) Overall objectives

We have two main objectives. The first pertains to the the basic biology of Atlantic salmon in the Bras d'Or Lakes ecosystem of Cape Breton. To what extent do Bras d'Or Atlantic salmon utilize local estuarine versus open-ocean migration strategies? We will test the hypothesis that some Atlantic salmon espouse a local over-winter migration strategy within the Bras d'Or estuary, whereas other fish will show longer-distance migrations out of the estuary into the North Atlantic Ocean. Our aim is to understand the physiological and environmental drivers of those decisions. The second objective addresses a management question: how does artifical spawning of wild fish influence their behaviour when returned to the wild. Using physiological sampling and acoustic telemetry, we are comparing the relative condition and migratory behaviour of salmon that are artifically spawned as part of a provincially run brood-stock program versus fish that spawn naturally in the wild.

b) Progress

Preliminary results suggest that the post-spawning condition of Atlantic salmon kelts predicts their migratory behaviour in terms of in migration timing and survival. Kelts in relatively good conditon (e.g. high relative body mass) at the time of sampling tended to remain in the natal river during the winter before migrating to the Bras d'Or Lakes in spring and then onwards to the Atlantic Ocean. This migration tactic was associated with high survival in spring and successful migration to sea. In contrast, poor condition fish tended to migrate immediately downstream to the Bras d'Or after release, choosing to overwinter there rather than in the river. Although we are awaiting more detection data from our acoustic receiver array, it appears that mortality was high in these poor condition fish, and none have yet been detected migrating to sea. In terms of the broodstock/wild comparison, broodstock fish have higher spost-spawning stress measures (plasma cortisol, lactate), and lower overall survival. Although these results suggest a potential effect of broodstock handling on the behaviour and survival of salmon, greater statistical power is needed. For the upcoming 2015 season beginning in November, we will repeat our 2014 tagging protocol, but will increase our sample size to 40 fish, thereby increasing the power of our comparisons. Continued analyses will also explore variation in habitat use within the Bras d'Or Lakes, and the environmental correlates of residencies.

c) Significant deviations

No signficant deviations.

d) Coordination and integration

The project was coordinated through the Bras d'Or Institute at Cape Breton University by undertaking regular field work and conversations with local partners (i.e. Atlantic Salmon Federation, DFO-BIO, Middle River Watershed Association, NS-DFA fish hatchery, UINR, Wagmatcook First Nation Guardians). Annual projet planning meetings were held with all parties in late August of each year, and formal presentations of results were made at semi-annual meetings of the Collaborative Salmon Initiative (CSI) and the Collaborative Environmental Planning Initiative (CEPI) for the Bras d'Or Lakes.

e) Scientific and/or engineering significance

Wild stocks of Atlantic salmon are at historically low levels throughout their range in the NW Atlantic. The causes are poorly understood, but there is indirect evidence of high levels of mortality at sea. The Bras d'Or estuary offers fish a unique opportunity to close their life cycle without venturing into the open ocean. This study has the potential to elucidate how the salmon populations of the Bras d'Or rivers have responded to this life history option, and what, if any, benefits those adaptation confer. The potential of the Bras d'Or Biosphere Reserve as a recovery refuge for the species cannot be ignored.

f) Significance of research to the community/public

The Atlantic salmon (Plamu) is of great cultural and spiritual significance to the Mi'kmaq people of the Bras d'Or Biosphere. The fish is also culturally and commercially significant to the Gaelic and Acadian communities of Cape Breton. It is fair to say that the public consider the health of salmon populations to be indicative of the health of the UNESCO Bras d'Or Biosphere Reserve. The interim results of this research are actively sought and followed by conservation groups, community organizations and the media.

7. Difficulties encountered

☒ Scientific problems/difficulties
☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)
☒ Involvement of partners
☒ Other (specify): see below

Scientific problems/difficulties: It proved very difficult to capture wild kelts in the late autumn, early winter of 2014. Despite several efforts by all partners (including several experienced anglers and seiners), we were only able to deploy 21 of our 25 tags. This reduced the sample size (and hence statistical power) of our experiment.

Equipment and technology issues (e.g. delivery and malfunctioning of equipment): The intended expansion of the Bras d'Or array to extend coverage into large sections of the estuary that have no receivers could not be completed because of a lack of funds for moorings. This compromised our abilities to depict the migration patterns of salmon within the estuary, and to estimate natural mortality

rates. Four of our VR-2W receivers deployed in the Middle and Baddeck rivers were vandalized during the course of the experiment (two on multiple occasions, two stolen and never recovered). A further two of the receivers were buried in sediment during river floods. These problems compromised our ability to determine the detailed movement patterns of salmon in the rivers.

Involvement of partners: There was no involvement of the partners in the Oceanography Department at Dalhousie. As a result, the numerical circulation model of the Bras d'Or estuary was not operationalized for the tracking experiments, and we were not able to simulate the oceanographic conditions through which our tagged fish moved.

Other: Transfers of funds to Cape Breton University from Dalhousie were greatly delayed, hindering the servicing of the Bras d'Or receiver array, and reducing the availability of personnel and boats.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

27 October 2014 –Crossin, Hatcher, Orr, Whoriskey. Teleconference to plan autumn tagging campaign.

30 October; 10,14,19,21 November; 2,12,15 December 2014; 20,21 January 2015 - Bordeleau, Crossin, Whoriskey (Dal); Hatcher, MacDougall, Murray, Orr, Penny (CBU); Christmas, Deny, C.Paul, T.Paul (UINR), Murrant, Neary (NS-DFA), Thompson (MRWA). Undertake joint fieldwork in the Middle and Baddeck rivers.

11,12,23,24,25 June; 6,12,16 July; 4,6,24,26 August; 11 September; 27 October, 2015 – Bates, Hatcher, Hayes, MacDougall, Murry, Orr, Penney, Whoriskey. Undertake joint fieldwork in the Bras d'Or array.

13-17 July 2015 – Bordeleau, 3rd International Conference on Fish Telemetry. Network with the Canadian and global OTN research community.

25 August 2015 – Crossin, Hatcher and several DFO and Provincial collaborators, community representative, and First Nations partners convened in Cape Breton for a Planning Meeting, where 2014 results were discussed, and 2015 field operations were discussed.

11 September 2015 – Hatcher, Rounds. MetaData configuration workshop, Bras d'Or Institute. Debug Bras d'Or Array metadata. Recover lost VR-4W receiver from fisherman in Glace Bay.

b) Interaction/Outreach to Broader Community

14 December 2014 – Hatcher; Mi'kmaq Elders; Chiefs from 4 First Nations communities; Mayors & Wardens from 4 Cape Breton Counties; DGs from: DFO, EC, TC, NS-DFA; DMs from: NS-DoE, NS-DNR. CEPI Senior Council Meeting, Eskasoni. Present and discuss results of salmon research in the Bras d'Or ecosystem to date.

17 March 2015 – Hatcher presents results of salmon tracking in the Bras d'Or estuary to the general public at CBU Research Week activity.

5 June 2015 – Hatcher participates in a meeting of the Cape Breton Collaborative Salmon Initiative (CSI) at the Margaree Fish Hatchery. Share results of salmon research with members of the Bras d'Or community.

26 August 2015 – Crossin, Hatcher and several DFO and Provincial collaborators, community representative, and First Nations partners convened in Cape Breton for a Planning Meeting, where 2014 results were discussed, and 2015 field operations were discussed.

2 Mar 15 – X. Bordeleau met with Shelley Denny (First Nations collaborator) to discuss spring fieldwork in Cape Breton.

17 Sep 15 – Crossin participated in a meeting with DFO and X. Bordeleau for the planning the 2015 field season.

28 Sep 15 – Meeting with K. Whoriskey and X. Bordeleau to discuss new ideas for spatial analysis of acoustic telemetry data.

29 Sep 15 – X. Bordeleau participated in OTN Toolbox training to learn about the program developed by OTN for the analysis of telemetry data.

30 Sep 15 – X. Bordeleau gave a demonstration of blood sampling procedure and discussed the role of physiology in telemetry studies (as part of BIOL 3600 – Aquaculture Lab).

26 Oct 15 – X. Bordeleau met with OTN collaborator Marie Auger-Methé to discuss potential OTN collaborators for expanding thesis introductory chapter into a review, meta-analysis, and modelling exercise (as part of the IdeasOTN initiative).

9. Dissemination of information and results

c) Conference presentations (1 total) – invited

Hatcher B, Crossin G, Orr M, Penney A. (2015) Migration decisions by Atlantic Salmon smolts in a complex estuary: Should they stay or should they go? Oral presentation. 52nd Annual Meeting of the Atlantic Society of Fish and Wildlife Biologists, St. Anne's Bay, 28 October, 2015.

d) Conference presentations (2 total) – contributed

Bordeleau X, Denny S, Whoriskey F, Hatcher BG, Orr M, Sheng J, Crossin GT (2015) Post-reproductive migration and physiology of Atlantic salmon in Cape Breton, NS. Poster presentation. 3rd International Conference on Fish Telemetry. Halifax, Nova Scotia, July 2015.

Hatcher B, Crossin G, Orr M, Penney A. (2015) Migration decisions by Atlantic Salmon smolts in a complex estuary: Should they stay or should they go? Oral presentation. Centennial Meeting of the Ecological Society of America, Baltimore, MD, 13 August, 2015.

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

2 June 15 – CBC Radio Interview on *Information Morning* - Hatcher discusses results of salmon research in the Bras d'Or Biosphere and its relevance to ecosystem health.

9 Jun 15 – TVO Television Documentary *Striking Balance* - Hatcher discusses results of salmon research in the Bras d'Or Biosphere Reserve and its relevance to the UNESCO Man and the Biosphere Programme.

5 Feb 15 – X. Bordeleau interviewed about Bras d'Or salmon research for article in The Cape Breton Star, published that day.

23 Feb 15 – X. Bordeleau interviewed by CBC Radio Information Morning about Bras d'Or salmon research, broadcast that day.

26 Aug 15 – Participated in a meeting with OTN PIs, First Nations partners, DFO and Province of Nova Scotia collaborators, as well as Atlantic Salmon Federation and community representatives for the planning of the 2015 field season. Bordeleau, Crossin, and Hatcher gave presentations about the results of the kelts and smolts work. News clippings of the meeting were published in the Victoria Standards (Issue of 31 Aug – 13 Sep).

2 Nov 15 – X. Bordeleau will participate in a follow-up radio interview for CBC (Cape Breton) Information Morning program discussing preliminary results from the first tagging season of Bras d'Or salmon.

b) Invited or contributed open-to-public presentation/contribution

12 Nov 14 – Hatcher. *Tagged and Tracked: inferring the fates of Atlantic Salmon in the Bras d'Or Lakes*. Cape Breton Naturalists Society, Sydney.

17 Mar 15 – Hatcher. *Tagged and Tracked: the secret lives of teen-aged Atlantic Salmon in the Bras d'Or estuary*. Cape Breton University Research Week. Sydney.

6 June 15 – X. Bordeleau participated in an OTN lobster tagging demonstration and discussed the role of telemetry in fisheries science and management (as part of Halifax Open Doors 2015).

c) Invited or contributed presentation/contribution at a workshop

28 July 15 – X. Bordeleau organized an afternoon about telemetry, the role of OTN, and how it has improved our ability to understand fish movement and manage our resources (as part of BIOL 3632 – Field Methods in Fish Ecology). Dr. Fred Whoriskey was invited to give a talk, followed by presentations by X. Bordeleau, then students worked on a group exercise that he developed.

12 Nov 15 – X. Bordeleau will give a presentation about preliminary results from the first tagging season of Bras d'Or salmon at the Recreational Fisheries Advisory Council in Cape Breton.

24 Nov 15 – X. Bordeleau will participate in the Collaborative Salmon Initiative annual meeting in Cape Breton (led by First Nation Partners).

d) Invited or contributed presentation/contribution at a seminar series

Hatcher. *Tracking the migrations of Atlantic Salmon using Acoustic Telemetry*. Ocean University of China, Qingdao, 16 October, 2014.

Hatcher. *Ecological connectivity of the Bras d'Or biosphere: self-sufficient lake or complex estuary?* Biology Departmental Seminar, University of New Brunswick, 20 March, 2015.

e) Awards received

Hatcher. Bras d'Or Lakes Golden Award. Presented by the Collaborative Environmental Planning Initiative (CEPI) at the World Water Day Celebration, Verschuren Centre for Sustainability in Energy and the Environment, Sydney, 25 March, 2015.

g) Data deposition to an agency/database (e.g., MEDS, GenBank, OBIS)

Records of ancillary species occurrences and oceanographic data from the Bras d'Or Array prepared for the OBIS as part of *Atlantic Canada's Biological Data for Ecosystem Planning and Decision-making: Opening Access and Increasing Reuse* project of the Atlantic Coastal Zone Information Steering Committee (ACZISC) funded by Environment Canada's Atlantic Ecosystem Initiatives. Hatcher, Kennedy, Walsh. June – September, 2015

h) Data deposition to OTN Data Centre

Bras d'Or Array metadata and VR-2W data files uploaded to the OTN database for 2015. Hatcher, Rounds & Bates. September, 2015.

m) Anything else that isn't a primary publication that has you communicating with others

Hatcher, BG. (2015) More Salmon Secrets from the Middle River. *The Blue Heron*. Bras d'Or Stewardship Society, Baddeck, NS. Vol.19(1): pp.9-10.

Hatcher, BG. (2015) The Secret Lives of Salmon in the Bras d'Or Biosphere. *The Cape Breton Community Post*. 22 July, 2015, page 4.

Hatcher, BG. Interview with C. Thompson, C. (2015) Atlantic Salmon Fallen on Hard Times. *Chronicle Herald-Cape Breton Star*. 2 September, 2015, page 3.

11. Collaborations with industrial and government partners

b) Contributions

Name of supporting organization: **CFI**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software (12 VEMCO VR-2W receivers)	36,000
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	YES

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff (assistance with planning: 3p-d)	1,200
2) Donation of equipment, software (recovery holding box)	450
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	YES

Name of supporting organization: **Nova Scotia Department of Fisheries and Aquaculture**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff (assistance with planning fish capture and release)	$3200
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	YES

Name of supporting organization: **Dalhousie University**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff (assistance with fish capture and release: 4 days)	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	YES

Name of supporting organization: **Hatcher Research Associates**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics (costs of un-reimbursed travel and consumables)	4,800
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	YES

Name of supporting organization: **Cape Breton University**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff (M.Orr, J.MacDougall, C.Murray: 16p-d)	6,400
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities (Truck, Boats, CTD, Dive gear, computers, Laboratory, workshop)	12,000
2) Salaries of managerial and administrative staff (Research, Personnel & Finance staff: 3p-d)	1,200
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	YES

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.5

2. Project Title: The biotic and abiotic control of the oceanic migrations of the threatened American eel

3. Project Leaders: Julian Dodson (U Laval), Martin Castonguay (DFO-Institut Maurice-Lamontagne, U Laval)

Other OTN Canada participants: R. Apostle, K. Fennel, J. Sheng, K. Thompson, D. VanderZwaag
Collaborators: Guy Verreault (Ministère des Fôrets, de la Faune et des Parcs (MFFP), Québec) and David Stanley (Ontario Power Generation, OPG)

4. Public summary of report

In October 2014, adult American eels caught in the St. Lawrence River were equipped with satellite tags and released off Nova Scotia. Several of these translocated eels migrated over hundreds of km in the open ocean including one individual tracked for approximatly 2400 km to the northern limit of the spawning area in the Sargasso Sea. This year's sucessful results provide the first direct evidence of adult American eels migrating to the Sargasso Sea and represent an important step forward in the understanding of routes and migratory cues. It proves the feasibility of revealing the migration routes despite the numerous challenges we are facing when tracking eels at sea (predation, low reporting rate, geolocation issues and uncertainty). A method to recontruct the daily locations of the tracked eels in absence of light data was developed. The speed and constant heading of the translocated eel tracked from the Scotian Shelf to the Sargasso Sea suggest that eels possess true navigation abilities, such as proposed for Pacific salmon. Results from all years of satellite experiments are reported in a paper that was accepted for publication in Nature Communications, illustrating the unique contribution of our research. During fall 2014, 52 silver eels were equipped with acoustic tags that record depth and were released in the St. Lawrence Estuary. So far, 5 eels were detected at the exit of the Gulf of St. Lawrence, providing the first information about the swimming depth of eels at that location and allowing to discard hypotheses about predation by homeothermic fish. Another aspect of our research project includes the development and application of two models that simulate the migration of adult eels: one from the St. Lawrence estuary to the exit of the Gulf and the other one from coastal waters to the spawning area in the Sargasso Sea. Both models represent valuable tools for testing various hypotheses. The model about the migration in the open ocean is described in a paper accepted for publication in ICES Journal of Marine Sciences and the second model will be submitted to another peer-reviewed journal in November 2015.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Mélanie Béguer-Pon	RA	100	100	17 Sept 2010	30 Sept 2016
Research Topic/current employment (if no longer OTNC HQP): Migratory behaviour of silver American eels					

b) Role, activities, and opportunities for training

Similar to previous years, the role of Mélanie Béguer-Pon was to lead in the data analysis as well as in publication writing. She was also involved in the field work by organising and participating in eel tagging that occurred in fall 2014 and fall 2015. She also collaborated with physical oceanographers (team of Theme I.1/Project 4.1), which helped improve her programming skills and her understanding of the physical environment surrounding eels. In late July 2015 Mélanie participated in a two-day workshop organised by OTN in Halifax. This workshop was about data vizualisation and state-space modelling, and allowed discovering and improving skills of essential tools for studying animal movements. Since April 2015, Mélanie has been part of ideasOTN committee which aims to raise OTN's profile, escalate PR, and demonstrate significant accomplishments and output, especially in Network Synthesis Activities, by taking the lead in developing (and authoring) synthesis papers. Mélanie also assisted with selecting abstracts for talks and for posters for the 3rd ICFT which was hosted by OTN in July 2015. Mélanie is also part of the local editorial committee which will publish conference proceedings in a special issue of the Environmental Biology of Fishes journal.

6. Progress towards objectives/milestones

a) Overall objectives

After over a century of research, the spawning migration of American eels remains a mystery. Neither the exact location of the spawning sites (which are somewhere in the vast southwest Sargasso Sea), the migratory routes or the environmental conditions that eels experience along the way are known. In the second phase of this OTN project, our main objective is to determine the migratory pattern of silver eels (i.e. maturing adults) from their departure in fresh waters to their spawning sites in the open ocean. To this end, we developed two complementary approaches. The first involves tracking movements of eels in the field using two different technologies: acoustic transmitters and satellite tags. The large-scale acoustic tracking conducted during OTN phase I documented the migration patterns of silver eels from the Saint Lawrence River to the Gulf. Their escapement at the exit of the Gulf (Cabot Strait) will continue to be documented via our partners from Ontario Power Generation and the Ministère des Forêts, de la Faune et des Parcs of Québec (MFFP) who acoustically tag and release silver eels each fall. The tagging experiments using satellite tags and that were initiated in fall 2011 will continue in an attempt to follow eels from the continental shelf to the spawning area in the Sargasso Sea. The second approach we initiated in late OTN phase I is the development, in collaboration with physical oceanographers from Project I.1.2, of two biophysical particle-tracking models that simulate the migration from the Saint Lawrence Estuary to the Scotian Shelf and from off the coasts to the Sargasso Sea, respectively. The objective of the first model (Gulf) is to test which behaviours can best reproduce the migratory pattern

revealed from our field tracking, while the objective of the second one (Open Ocean) is to assess the effect of the flow field on various likely orientation behaviours (and thus routes).

b) Progress

Our most significant progress and accomplishement comes from the satellite tracking experiment conducted in late 2014. Mid-October 2014, 16 silver eels equipped with satellite tags (mainly X-tags) were released off Nova Scotia. Contrary to previous year's experiments and based on their results, we decided to tag eels that were translocated by truck from the St. Lawrence River Estuary to the Scotian Shelf. It allowed us to tag the largest eels that can be found in the entire species range (thus minimizing the negative effects of drag caused by the external tags) and to avoid the Gulf of St. Lawrence which seems to be a high natural predation area by homeothermic fish as revealed by our experiment conducted in 2011. While all tags popped prematurely and some never reported (as in previous years), several eels were tracked beyond the Scotian Shelf with one individual migrating approximatly 2400 km until the northern limit of the spawning area in the Sargasso Sea. Our results provide the first direct evidence of adult American eels migrating to the Sargasso Sea (until then, no adult has ever been tracked or caught in the open ocean and the spawning area has been inferred from the collection of larvae). It represents an important step forward in understanding the migration of this most enigmatic of species (please see section e)) and illustrates the feasibility of revealing in even greater detail the migration routes and orientation cues eels use to complete their life cyle. These results, along with those from previous years experiments (with eels released off the continental Shelf) are reported in a paper accepted for publication in Nature Communications. Given the increasing success of our satellite tagging experiments over the years (since 2011), additional experiments using protocols similar to those used last year must be pursued to confirm the migratory patterns we have documented. In October 2015, we will equip 14 large eels caught in the St. Lawrence River Estuary with satellite tags (X-tags from Microwave Telemetry) and we will release them off the tip of Cape Breton Island (Nova Scotia) directly in Cabot Strait. Half of the satellite tags will be programmed to report mid-January and the other half mid-March 2016. This new experiment will provide new data that will be compared to our previous results.

Additional information on the migratory behaviour of silver eels from the Saint Lawrence Estuary to the exit of the Gulf (Cabot Strait) were acquired during winter 2014 thanks to detections made by the acoustic receivers moored at the Cabot Strait. In October 2014, our partners from the Ministère des Forêts, de la Faune et des Parcs of Québec (MFFP) in collaboration with Ontario Power Generation (OPG) tagged 52 silver eels with new acoustic tags equipped with temperature sensors (based on our recommandations). Five eels were detected at Cabot Strait Line in November and December 2014. However, the receivers from the eastern portion of the Cabot Strait Line have not been downloaded yet and thus potential additional detections could increase the number of detected eels. Temperature data recorded by the 5 tags provided new useful information: depth ranges at which eels crossed the Cabot Strait were evaluated and the assumption of predation by homeothermic fishes was rejected as tags did not register any abnormal temperature. Fall 2014 was the last year of acoustic experiments conducted by our partners from MFFP and OPG. Once all the data from Cabot Strait Line are available, a paper reporting the detections of silver eels made in the Gulf and at its exit will be prepared in collaboration with them (Winter-Spring 2016).

A wave glider equipped with an acoustic receiver was deployed in December 2014 in an attempt to detect more tagged eels in the vincity of the Cabot Strait Line. Unfortunatly no eels were detected during the 3-day deployment of the glider.

In parallel we continued to work on the two biophysical particle-tracking models developed with the physical oceanographers from OTN team of Theme I.1(Kyoko Ohashi, Jinyu Sheng, Shiliang Shan and Keith R. Thompson from the Department of Oceanography, Dalhousie University). The paper that reports results from the simulation of the migration in the open ocean, offshore to the Sargasso Sea for both American and European eels, was submitted to the ICES Journal of Marine Sciences in early December 2014. After several modifications it was accepted for publication in that journal in September 2015 and is currently in press. The paper will be part of a symposium issue on Anguillid eels that stems from the Eel symposium that took place in Québec City during AFS 2014. Due to important modifications in the physical model developed by Dr Kyoko Ohashi and Dr Jinuy Sheng, the various experiments that simulate the migration of eels from the St. Lawrence estuary to the exit of the Gulf had to be reconducted during spring 2015. A paper that reports these results was written during Summer 2015 and will be submitted to a peer-reviewed journal in November 2015.

c) Significant deviations

There was no significant deviations from our original objectives.

d) Coordination and integration

Dr Mélanie Béguer is in charge of maintaining the communication between project's co-investigators and collaborators. Since Mélanie is located in the Department of Oceanography, at Dalhousie University in Halifax, the collaboration with physical oceanographers from OTN theme I.1. has been considerably facilitated and occurs through regular and numerous face-to-face meetings. The field tracking experiment (using satellite tags) took place in Nova Scotia in mid-October 2014, which allowed the active participation of the physical oceanographers Shiliang Shan and Kyoko Ohashi. Regular communications with the PIs are maintained, mainly by emails but also by monthly virtual conferences. We also met during the field experiments (October 2014 and October 2015).

e) Scientific and/or engineering significance

Our satellite tagging experiments provided the first direct evidence of adult Anguilla migrating to the Sargasso Sea and represent an important step forward in the understanding of routes and migratory cues. Until now, the oceanic migration of adult American eels had remained a mystery: no adult has ever been caught in the open ocean or in the Sargasso Sea. Neither the migratory routes, the environmental conditions they experience along the way nor the exact location of the spawning site are known. The oceanic migration of adult American eels from the coast to the spawning area have only been previously inferred from the collection and distribution of larvae over a century ago. Since fall 2011, we have equipped a total of 49 eels with pop-up satellite archival tags. Seven of the 11 eels released in the Gulf during the first years of experiment were predated shortly after their release. It was thus decided to release tagged eels directly over the continental shelf and to translocate them from the St. Lawrence Estuary in order to tag the largest individuals that can be found and to increase the likelihood of observing complete migrations. Thereby, of the 38 eels equipped with satellite tags and released over the continental shelf, we succeeded in tracking 8 eels to the open ocean, including one tracked for approximatly 2400 km to the northern limit of the spawning site in the Sargasso Sea. We developed a method to reconstruct daily locations using the environmental data recorded by the tags, the bathymetry and ouputs of operational global ocean circulation models that have advanced data assimilation components (in collaboration with Shiliang Shan, physical oceanographer from OTN theme I.1). Traditional methods performed to infer location of tracked marine species could not be used as they are

based on light data that were not available in our case due to the propensity of eels to avoid the euphotic zone during daytime. The migratory paths were reconstructed for 20 eels, with an average uncertainty of about 140 km in latitude and 230 km in longitude. The reconstructed paths indicate a migration distance between approximatly 1300 and 1700 km for four eels and 2400 km for the eel that reached the Sargasso Sea. Despite differences in release years, locations, as well as eel origins, similar paths and vertical behaviours were observed. This indicates a degree of consistency in the orientation/navigation mechanisms employed throughout the migration. Two distinct migratory phases were identified: one in shallow waters over the continental shelf and the other in deep waters off the shelf. The first phase of the marine migration may simply rely on gradients and fronts associated with salinity and temperature while the speed and directionality of the eel tracked in the Sargasso Sea suggests the involvement of an inherited bi-dimensional map similar to that proposed for Pacific salmon for instance. Diel vertical migration down to 700 m in the open ocean were observed. The migratory routes seem to be largely independent of current fields. These results are reported in a paper entitled "Direct observations of American eels migrating accross the continental shelf to the Sargasso Sea" that was accepted for publication in September 2015 in Nature Communications. Fourteen large eels from the Saint Lawrence River will be equipped mid-October 2015 with satellite tags (X-tags) and released off Nova Scotia (off CapeBreton, NS) over the Laurentian Channel. We thus hope that this last year of satellite tagging experiment will provide additional results and will confirm the migratory patterns we have documented so far.

Of the 52 eels equipped with acoustic transmitters that collect temperature and released in the St. Lawrence estuary in October 2014, 5 individuals (total of 471 detections) were detected at the exit of the Gulf of St. Lawrence (Cabot Strait Line). The observed migration durations in the Gulf are within the range observed from previous year's data and none of them appears too high to be unrealistic (i.e. could not correspond to tagged eels). All eels were detected at receivers moored in the vicinity of St. Paul Island, above 200-400 m depth. The low detection rate (9.6%) was also similar to previous years. However, several receivers from the Cabot Strait Line still remain to be downloaded so more data might be available in the upcoming weeks and present results must be considered as preliminary. Temperature values recorded by the 5 tags allow rejecting the assumption of predation by homeothermic fish. Temperature values were matched with data-assimilated physical models and indicate eels were in deepers waters during daytime (150 to 400 m) than at night (0 to 150 m) when detected at Cabot Strait. This is consistent with the diel vertical migration behaviour observed from our satellite tagging experiments conducted in the Gulf. These acoustic data represents new information about the vertical behaviour at the exit of the Gulf. The estimated depths show eels can cross the CBS line either close to the surface or very deep, depending on the hour of the day. It is therefore unwarranted to conclude that the low detection rate at the Cabot line obtained each year is due to a low detection efficiency of the receivers that are moored close to the bottom (down to 480 m).

Two bio-physical particle-tracking models were developed in collaboration with OTN theme I.1 in order to simulate the migration of silver eels i) from the Saint Lawrence estuary to the exit of the Gulf and ii) from the coasts to the Sargasso Sea. Since last year's report, some modifications were done (improvement of physical model and modification of output analysis) so significant additional work was conducted for both models during 2015. The paper that reports results from the simulation of the migration in the open ocean, offshore to the Sargasso Sea for both American and Europeen eels was accepted for publication in the ICES Journal of Marine Sciences (September 2015). The paper is entitled "Exploring the role of the physical marine envionment on silver eel migration using biophysical particle-tracking model". In this paper, two plausible swimming directed behaviours were considered for simulating two different migratory paths: true navigation to specific spawning sites and innate compass

orientation toward the vast spawning area. Several combinations of swimming speeds and depths were tested to assess the effect of ocean circulation on resulting migratory pathways of virtual eels (v-eels), environmental conditions experienced along their oceanic migration, and energy consumption. Simulations showed that the spawning area can be reached in time by constantly swimming and following a readjusted heading (true navigation) or a constant heading (compass orientation) even at the lowest swimming speed tested (0.2 m s-1) for most v-eels. The ocean currents affect mainly the migration of American v-eels particularly for swimming speeds lower than 0.8 m s-1. The ocean circulation increases the variability in the oceanic migration and generally reduces the efficiency of the v-eels although positive effects can be possible for certain individuals. The depth range of diel vertical migration significantly affects the total energy expenditure due to the water temperature experienced at the various depths. Model results also suggest that energy would not be a limiting factor as v-eels constantly swimming at 0.8 BL s-1 spent less than 25% and 42% of energy available for migration for American and European v-eels, respectively.

Experiments and outputs from the second model that simulates the migration of adult American eels from the St. Lawrence estuary to the exit of the Gulf are reported in a paper that will be submitted to a peer-reviewed journal in November 2015. Our paper illustrates how an individual-based model coupled with a circulation model can help clarifying the behaviour of tracked fish and can complement ongoing and future telemetry experiments. Several numerical experiments that combine vertical and horizontal behaviours of v-eels were conducted to evaluate which ones allow better reproducing/matching the migratory pattern observed from the satellite and acoustic tagging experiments. Results showed that v-eels migrating through the St. Lawrence Estuary and Gulf must employ very efficient swimming and complex orientation stategies to migrate within the time window observed from telemetry experiments. Active Selective Tidal Stream Transport is one such important strategy for escaping the estuary. Orientation toward higher salinity and/or greater depth did not appear sufficient and suggests other orientation cues such as the geomagnetic field gradient are required. Results also showed that some of the shortest observed duration of migration (from telemetry experiments) would require unrealistically high swimming speeds, suggesting predation of corresponding tagged eels detected at the exit of the Gulf. The model we developed can also be used as a tool for evaluating the potential effect of climatic change on the timing of eels' migration in the Gulf of St. Lawrence. The numerical experiments conducted using various St. Lawrence River discharge conditions showed that the duration of migration of v-eels in the Gulf was increased by 10 days on average during low discharge conditions compared to high ones. The numerical experiments we have conducted were a first step in exploring the effect of the St. Lawrence River discharge on the migration of eels in the Gulf and more experiments that will include discharge of tributaries and their projected changes from various scenarios of climatic change are needed to address this important question.

f) Significance of research to the community/public

American eels spend their juvenile growth stage in various habitats of the continental waters (lakes, rivers, estuaries, marine coastal waters). After several years (up to 25), eels start to mature and undertake an amazing long-distance migration (up to 4,000 km) from continental waters to a single spawning area in the Sargasso Sea. After over a century of research that has failed to catch a single adult in the open ocean, most information concerning that spawning migration remains a complete mystery. The spawning area was located thanks to the collection of larvae and the migration routes of adults to reach this area are unknown. Our current research aims at shedding some light on the oceanic migration of American eels. Filling this knowledge gap is very important for both research and management objectives, especially in a context of the precarious status of the species. American eels are indeed listed

as endangered on the ICN red list and assessed as threatened in Canada. We use various complementary approaches to document the migration of the American eel at sea. One approach consists of tracking eels using two different telemetry technologies. We track maturing eels from freshwaters of the upper St. Lawrence system to the exit of the Gulf using acoustic transmitters implanted in the abdominal cavity of eels. Their presence is recorded by hydrophones moored at various location along the way. The migration in marine waters (i.e. in the Gulf of St. Lawrence and open ocean) is also assessed using pop-up satellite archival tags. These external tags are attached to the back of the eels and are programmed to record several environmental data such as temperature and depth for several months. We retrieve these data only when the tags detach themselves from the eels and reach the surface where they can transmit to satellites. We then develop methods to reconstruct the migration routes of the tagged eels using the environmental data collected by the satellite tags (we don't have any gps location unfortunately!). Another approach that is complementary to the field tracking is the simulation of the eels migration using ocean circulation models. We program virtual eels to move vertically and horizontally, according to the behaviours observed during our field experiments, and we track their movement in order to test various hypothesis.

Altogether, these approaches allowed us to document the patterns and behaviours of maturing eels from the upper St. Lawrence to the Sargasso Sea. The timing and duration of migration were assessed in the various sections of the St. Lawrence system. A very high varibility among individuals was revealed. We demonstrated that eels migrate mainly at night and use the current to efficienly espace the estuary. Simulations have shown that eels must employ very efficient swimming and complex orientation strategies to migrate through the Gulf within the time window observed from telemetry experiments. In the Gulf, eels travelled in the deep Laurentian Channel probably taking advantage of the main outgoing current. They do diel vertical migrations, i.e. are close to the surface at night and deeper during the day, in the Gulf (up to 370 m) but also in the Sargasso Sea (up to 700 m). Our research suggests a high natural predation rate in the Gulf (by sharks and tunas) and also over the continental shelf. Indeed several of the eels tagged with satellite tags were clearly preyed upon and simulations of migration in the Gulf demonstrate unrealistic swimming speeds for them to correspond to eels. Because very few eels were detected at the exit of the Gulf despite a very large number of tagged individuals (several hundreds), we also suspect that a non negligible part of the the population component that initiate their migration in the upper St. Lawrence can temporarilly suspend migration and resume it the following year but this aspect requires further investigation. So far, we have been able to track 8 eels equipped with satellite tags from the marine coastal waters of the continental shelf to the open ocean off the shelf, including one eel tracked for 2400 km to the northern limit of the spawning area in the Sargasso Sea! These results represent the first direct evidence of adults American eel migrating to and in the Sargasso Sea. We observed two distinct migratory phases: one in shallow waters over the continental shelf and the other in deeper waters off the shelf. While the eels could simply use the salinity and temperature as environmental cues to orientate during the first phase of the marine migration, the speed and consistent directionality of the eel tracked to the Sargasso Sea suggest that eels possess a magnetic map and true navigation abilities such as demonstrated for salmon. Furthermore, the oceanic migratory routes seem to be largely independent of current fields since tracked eels mainly travelled against it. Simulations from our developed model also show that oceanic currents have a significant impact only for eels swimming at low speed. The model also shows that energy would not be a limiting factor for eels to reach the spawning site. Our research represents a significant step in understanding the migration of this most enigmatic of species. It shows that despite many challenges (predation, absence of light data, size of the satellite tags) it is now feasible to shed some important light on a mystery that has puzzled and fascinated scientists for over a century!

7. Difficulties encountered

☒ Scientific problems/difficulties
☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)

At the onset of our research project, we were hoping that the satellite tags would be improved over the years but it did not happen. Specifications of satellite tags remained almost the same since their development and their first use on eels over fifteen years ago. Their size is one of the main issues. Several laboratory studies have demonstrated that pop-up satellite archival tags increase drag and can significantly impair the swimming performance of relatively small eels. To minimize the impact of the external tags on eels, we used the largest eels that can be found, i.e. eels from the St. Lawrence River, and we chose to release them directly over the continental shelf rather than in the Gulf where the natural predation rate seems very high. Although our approach of translocation proved to be relatively successful, the possibility that the tags may have contributed to slower speeds of eels and to the more westerly pop-up locations on the Scotian Shelf cannot be discarded. Another drawback of using PSATs is associated with the limitations of retrieving recorded data and its impact on the reconstruction of migratory paths (15-min intervals of archival data and low sensitivity to light data).

An important rate of non-reporting by tags and premature releases were two important issues encountered in our research. Our overall loss rate of tags was 26.3% which is approximately the same as other satellite tags studies in eels (11.1 to 32 %) and close to the average from a review conducted on the performance of satellite tags on other fish species (21%). The reasons for non-reports are unknown but could be due to tag malfunctioning, destruction by predation or inability of the tag to transmit their data to satellites. However, our non-reporting rate significantly decreased over the years (70% in 2012, 17% in 2013 and 6% in 2014) which could be due to our modified approach of tagging larger eels and not releasing them directly from the shore but 5-10 km offshore over deeper waters. Several predation events have also been identified during our study which involved eels released over the continental shelf (in addition to eels released in the Gulf where an important predation rate was already highlighted by our experiments conducted in 2011). Two eels were clearly eaten by homeothermic fish and seven of the eels could have been predated by ectothermic fish.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

We continue to actively collaborate with physical oceanographers from OTN theme I. Due to the presence of Mélanie at Dalhousie University, she has been able to work closely with all participants through numerous meetings. This collaboration generated two publications: one that was accepted in the ICES Journal of Marine Sciences and one that will be submitted to Animal migration journal soon. In parallel with these modelling works, Shiliang Shang has also been involved in the development of a method to infer the location of eels tracked using the satellite tags. This method and associated results are very important components of the publication accepted in Nature communications. Also, the physical oceanographers actively participate in our yearly field satellite tracking experiments.

We have been communicating with David VanderZwaag (OTN member, lawyer at Dalhousie University) and we helped to review a concept paper written for the American Eel Symposium which will be held in October 2015 at the University of Maine Law School. The objective of the symposium is to provide an informed discussion between the Scientific, Legal and Policity communities in the US and Canada on

the conservation status and the needs of the American eel. Dr Martin Castonguay will attend the symposium.

b) Interaction/Outreach to Broader Community

As in previous years we collaborated with the Ministère des Forêts, de la Faune et des Parcs (MFFP) and Ontario Power Generation (OPG) who tagged silver eels in the Saint Lawrence River in fall 2014 in order to detect them at Cabot Strait line. Their goals regarding the eels are more for management purpose (comparison between stocked and wild eels) but their data provides additional information about eel movement at that location, allowing us to feed our biophysical particle-tracking models and test hypothesis about eels behaviours. Detections are shared between all partners and results are discussed by email/phone. Based on previous results and on our recommandations, they decided to use acoustic tags equipped with temperature sensors in October 2014. So far 5 eels equipped with such tags were detected at Cabot Strait providing new useful information: depth ranges at which eels were when crossing the Cabot Strait and direct proof of non-predation of these detected tags by homeothermic fish. Fall 2014 was the last year of acoustic experiments conducted by our parterns from MFFP and OPG. A paper reporting the results from their experiments will be prepared in collaboration with them (Winter-Spring 2016).

9. Dissemination of information and results

a) Refereed journal articles (3 total) – accepted/published

Béguer-Pon M, Castonguay, M., Shan, S., Benchetrit, J. and Dodson, J. J. (in press) Direct observations of American eels migrating accross the continental shelf to the Sargasso Sea. Nature Communications. NCOMMS-15-06624B, DOI not yet available

Béguer-Pon, M., Shan, S., Thompson, K., Castonguay, M., Sheng, J. & Dodson, J. J. (In press) Exploring the role of the physical marine environment on silver eel migration using biophysical particle-tracking model. ICES Journal of Marine Science: 10.1093/icesjms/fsv169.

Benchetrit, J., Béguer-Pon, M., Sirois, P., Castonguay, M., Fitzsimons, J. & Dodson, J. J. (2015) Using otolith microchemistry to reconstruct habitat use of American eels Anguilla rostrata in the St. Lawrence River–Lake Ontario system. Ecology of Freshwater Fish: DOI 10.1111/eff.12246. Web link : http://onlinelibrary.wiley.com/doi/10.1111/eff.12246/abstract

b) Refereed journal articles (1 total) – submitted

Béguer-Pon, M., Ohashi, K., Sheng, J., Castonguay, M. & Dodson, J. J. (Submitted November 2015) Using an individual-based model coupled with an ocean circulation model to determine the behaviour of tracked fish: case of the American eel migration in the Gulf of St. Lawrence. MPES.

c) Conference presentations (1 total) – invited

Castonguay, M., Béguer-Pon, M., Shan, S., Benchetrit, Dodson, J. (2015) La migration océanique de l'anguille d'Amérique. Conférence sur invitation à IRSTEA, Bordeaux, France, 9 June 2015.

d) Conference presentations (1 total) – contributed

Béguer-Pon, M., Shan, S., Benchetrit, J., Castonguay, M. & Dodson, J. (2015) Oceanic scale spawning migration pattern of the American eel. Oral presentation at the 3rd International Conference on Fish Telemetry, Halifax, Nova Scotia, Canada. 13-17 July 2015.

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

Martin Castonguay gave a skype interview for the Canadian show "Années Lumière" that was broadcasted by Radio Canada in August 2015.
http://ici.radio-canada.ca/emissions/les_annees_lumiere/2009-2010/chronique.asp?idChronique=381043 (minute 41, 12h41, in French).

h) Data deposition to OTN Data Centre

Metadata about the acoustic tagging of 52 eels and the equipement of 16 eels with satellite tags were deposited to OTN Data Centre in fall/winter 2014. Data from the satellite tagging experiments conducted in late 2014 were deposited during summer 2015.

i) Invited or contributed consultations (e.g., stock assessment meetings, contributions to policy/management decisions, etc.)

Bermudian Eels. What happens in the Sargasso stays in the Sargasso (for now), published online on April 17, 2017 by Elizabeth Halliday, Science Writer at Bermuda Institute of Ocean Sciences (BIOS) following skype interview of Dr Mélanie Béguer.
http://www.thebermudian.com/66-myblog/home-grown-made-in-bermuda/1582-bermudian-eels

p) A new technology, method, protocol, measure, analytical technique, algorithm, operational or numerical model, or predictive tool. Include the validation of any of the former and their practical application

Since 2011, our success from our satellite tagging experiments has significantly been increasing. To our knowledge, such multi-year research effort is the first one that was ever conducted to track adult eels at sea using satellite tags. We believe that we can now provide useful recommandations for further similar studies: the eels should be released offshore over deep waters, the largest (>2 kg) only should be tagged considering the current size of the satellite tags and eels can be translocated toward a more favorable releasing area, at several hundred of km from their capture site. We also developed a method to reconstruct the daily location of the tracked eels based on environmental data (temperature, depth and geomagnetic field intensity) that were matched with bathymetry and outputs of strongly assimilated physical models. This method can be used for other species for which the use of traditional geolocation method is prevented from the absence of light data.

Both numerical models developed in collaboration with physical oceanographers from OTN theme I.1 represent useful tools that can help determining the behaviours of tracked eels and that can complement

ongoing and future telemetry experiments. These models were developed for studying the eel migration but can be applied for other species such as the post-smolt Atlantic salmon that migrate in the Gulf of St. Lawrence (case study presented by Dr Kyoko Ohashi at the 3rd International Conference on Fish Telemetry). Both models can be used for assessing swimming speeds and behaviours required for matching observed data, and therefore for testing various hypothesis such as the predation of tagged eels. The models can also be used as tools for evaluating the potential effect of climatic change on the timing of eels's migration. The model that simulates the migration in the open ocean allows to calculate the energy expenditure along the migratory path. This can serve for assessing the minimum energy required for the success of migration or assess effect of pollutants/bad conditions of eels on their success for instance (the only parameter to be changed would be the energy intial reserve).

11. Collaborations with industrial and government partners

a) Partners

We collaborate with Guy Verreault from the Ministère des Forêts, de le Faune et des Parcs (MFFP) (Québec) and with Dave Stanley from Ontario Power Generation (OPG-Ontario). Their objective is to assess the effectiveness of a stocking program that was conducted few years ago in the upper St. Lawrence with glass eels caught in Nova Scotia. The stocked silver eels initiate their migration at much smaller sizes than the wild ones. Therefore, the managers want to assess if the stocked eels are able to migrate out the estuary and Gulf like the wild larger ones, and are particularly interested in the detections at the Cabot Strait line. Our partners from MFFP-Québec and OPG buy the acoustic tags, do the tagging and send their metadata directly to OTN database managers or to Dr Béguer-Pon who transfers them. We forward them the detections when available, as well as a quick report of results. These detections provide very useful information about the escapement of eels from the Gulf, which is one of the objectives of our project. These data are also very useful for our numerical experiments which can also serve to highlight suspicious detections (possible predation).

b) Contributions

Name of supporting organization: **CFI**	**Year 6** (2015)
Cash contributions to direct costs of research	$60,020
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 6** (2015)
Cash contributions to direct costs of research	$4,000
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$22,000
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$500
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	$26,500
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **OPG (MRNF supported by OPG)**	**Year 6** (2014)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
Salaries for scientific and technical staff – MFFP salaries and eels	14,000
Donation of equipment, software – Vemco tags	29,000
Donation of material	
Field work logistics	
Provision of services	
Other (specify):	
In-kind contributions to indirect costs of research	
Use of organization's facilities	
Salaries of managerial and administrative staff OPG salary and admin costs	10,000
Other (specify):	
Total of all in-kind contributions	53,000

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.6

2. Project Title: Movement and habitat use by sturgeon in Atlantic Canada and anthropogenic interactions

3. Project Leaders: Mike Stokesbury (Acadia U), Michael Dadswell (Acadia U), Matthew Litvak (Mount Alison U)

Other OTN Canada participants: R. Apostle, S. Cooke, C. Taggart, J. Sheng, D. Vanderzwaag, G. Crossin

Collaborators: Colin Simpfendorfer and Michelle Hueple (James Cook University, Australia), Kevin Stokesbury (U. Mass, USA), Matt Balazak (Virginia Commonwealth U., USA), Ike Wirgin (NYU Langone Medical School, NY, USA), Cornel Ceapa (Acadian Sturgeon and Caviar), Rod Bradford, (BIO, DFO, NS, Canada

4. Public summary of report

We are tagging Atlantic sturgeon from the mixed stock aggregation that migrates every summer through Minas Passage, NS, and into and out of Minas Basin. The sturgeon are from the Saint John River N. B., Kennebec River, ME, USA and rivers further south in the USA (James and Hudson). This year we tagged sturgeon with acoustic coded-pingers, conventional tags (Floy), Passive Integrative Transponders, and a Wildlife Computers Splash tag. A modified Schnabel population estimate based on recaptures of sturgeon with external Floy tags and total captures of 1843 sturgeon in Minas Basin during 2015 determined the summer aggregation consisted of approximately 38,345 (95% CL 31,954 – 46,880) individuals. We now have ~1450 floy tagged sturgeon at large. During 2015, our work on the Minas Basin mixed stock aggregation focused on tagging sturgeon with multiple technologies (e.g. both acoustic and archival tags) to retrieve datasets by acoustic reception during summer residency in Minas Basin and during passage through Minas Passage and to determine if there is population specific movement. Information on temporal and spatial distribution, including depth, is central to predicting overlap between migrating sturgeon and hydropower turbines scheduled to be deployed in late fall 2015. In collaboration with DFO, and industry (Acadian Sturgeon and Caviar Inc.) we determined the growth rate of sturgeon from the Saint John River therefore filling a critical data gap. We also assisted Acadian Sturgeon and Caviar in assessing the total population size of adult Atlantic sturgeon in the Saint John River for management purposes. Our estimate indicates the total adult Atlantic sturgeon population in the Saint John is approximarely 18,000 fish and exploitation is 2 %/year under the present managent regime.

Sturgeon, acoustically tagged in Minas Basin during past years, were recorded on arrays owned by Vemco (Shag Harbour NS), University of New Brunswick (Allen Curry) and the US government (Graham Goulet NOAA off Maine, USA). Weir fishers who collaborate with our project captured Atlantic sturgeon tagged in the Penobscot River [1], Hudson River [1] and Saint John River [8] Results from our project are currently being used by Canadian and USA government departments for fisheries management and endangered species decisions.

In the Saint John River, we have determined the timing and location of spawning and spawning periodicity. In spring 2015, we tagged 13 juvenile Atlantic sturgeon in the Saint John [6], Kennebacasis [6] and Petitcodiac [1] Rivers. Tracking of these individuals has been ongoing and will continue through fall and winter of 2015. We have also determined movement and aggregation areas of juvenile Atlantic sturgeon in the Saint John River. Our results suggest the potential for overlap in foraging areas and prey items between juvenile Atlantic sturgeon and shortnose sturgeon in the Saint John River.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title*	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Laura Logan-Chesney	MSc	100	100	1 Sept 2012	2016
Research Topic/current employment (if no longer OTNC HQP): Breaching behaviour and Population specific movements of Atlantic Sturgeon in Minas Basin					
Colin Buhariwalla	MSc		0	1 Sept 2012	2016
Research Topic/current employment (if no longer OTNC HQP): Habitat Utilization and Movements of Striped Bass in the Mira River, NS					
Seth Newell	MSc	100	100	1 May 2015	1 Sept 2015
Research Topic: Spawning periodicity of Atlantic sturgeon in the Saint John River					
Andrew Taylor	choose	100	0	1 May 2010	1 Dec 2014
Research Topic: Seasonal distribution, movement patterns, and habitat use of Atlantic sturgeon from the Saint John River, New Brunswick, Canada					
Margaret Whitmore	research assistant	100	100	11 July 2015	Sept 2017
Research Topic: Seasonal distribution, movement patterns, and habitat use of juvenile Atlantic sturgeon from the Saint John River, New Brunswick, Canada					
Matthew Brown	research assistant	100	100	1 May 2014	1 May 2016
Research Topic: Seasonal distribution, movement patterns, and habitat use of Atlantic sturgeon from the Saint John River, New Brunswick, Canada					
Christine Gilroy	research assistant	15	0	2 March 2015	1 May 2016
Research Topic: a) Shortnose sturgeon angling best practices. b) Efficacy of accelerometry to determine sturgeon behaviour.					
Elizabeth MacDonald	research assistant	10	0	8 Sept 2015	31 Dec 2015
Research Topic: a) Shortnose sturgeon angling best practices. b) Efficacy of accelerometry to determine sturgeon behaviour.					
Keyvan Balazadeh	MSc	15	0	5 October 2014	Dec 2016
Research Topic: Seasonal distribution, movement patterns, and habitat use of Atlantic sturgeon from the Saint John River, New Brunswick, Canada					

b) Role, activities, and opportunities for training

Our HQP's are integrated into every facet of our research program. HQP prepare and deploy receivers, operate on and acoustically tag fish and design attachment equipment and attach archival pop-up tags and Splash tags to fish. They sample fish for morphological characteristics (length, weight, etc.), collect samples for DNA analysis, stable isotope analysis, larval sampling and observe and help collect parasites. They are involved in active and passive fish tracking. They have developed new harness systems that have proven very reliable for keeping PAT (MK10 and mini-PAT) tags and Splash tags attached to free ranging sturgeon. They assist in record keeping and data analysis, including submission

of meta-data to the OTN data centre and train in collaboration with the OTN data management team. Most HQP's have become skilled in using data analysis packages such as "R" in advanced data analysis of movement and behavior data. Students independently write-up results for primary publications (see Publications and note many papers have HQPs as first author). They present results at international and local scientific meetings from portions of the study for which they are responsible.

6. Progress towards objectives/milestones

a) Overall objectives

1. Determine the migratory behavior and origin of Atlantic Sturgeon on the east coast of Canada.

2. Describe the annual, summer migration of Atlantic Sturgeon through Minas Passage and Minas Basin and the population characteristics movements, and size of this aggregation.

3. Determine the importance of Minas Basin to the growth of Atlantic Sturgeon.

4. Determine the movement of Atlantic Sturgeon through Minas Passage and the potential impact of tidal power on east coast stocks.

5. Describe movements to these potential spawning areas, spawning periodicity of adults in the Saint John River, and differences in timing and behaviour of spawning migration between male and female fish.

6. Describe habitat in the potential over-winter area in the Bay of Fundy.

7. Continue to monitor movements, feeding ecology, and determine summer and winter aggregation areas of juvenile Atlantic sturgeon in the Saint John and Kennebecasis Rivers.

8. Collaborate with First Nations and local fishers to begin tagging Atlantic sturgeon in the Miramichi and Petitcodiac Rivers.

9. Communicate our findings locally, nationally and internationally through meetings, presentations and publications.

b) Progress

1. Acoustic and Archival Tags are providing new insight into the movement and migration of Atlantic Sturgeon tagged in the Minas Basin and the Saint John River. Laura Logan-Chesney (MSc at Acadia) is working with Ike Wirgin (NYU Langone Medical School, NY, USA) to determine through genetics the origin of Atlantic Sturgeon captured and tagged in Minas Basin. She is assessing population specific breaching behaviour movement and migrational characteristics for acoustically-tagged sturgeon in Minas Basin and Minas Passage.

2. Laura Logan-Chesney continues to analyse the MPS and MPD data sets to describe annual migrations and population characteristics for sturgeon tagged in Minas Basin. Data from double tagged sturgeon (acoustic and archival tags), is providing new insights into vertical and horizontal distribution in Minas Passage in relation to tidal power turbine deployment scheduled for late 2015.

3. Nathen Stewart of Acadia in collaboration with DFO (Dr. Rod Bradford) and industry (Dr. Cornel Ceapa of Acadian Sturgeon and Caviar Ltd.) analyzed historical and recently provided (by the sturgeon fishing industry) pectoral spines of Atlantic Sturgeon to determine the length-age relationship and von Bertalanffy growth parameters that are critical for management of the population. This paper is now published in the North American Journal of Fisheries Management.

4. A report was prepared for the OERA detailing the movement of Atlantic Sturgeon through Minas Passage using acoustic tags. This document identified the need to link acoustic and archival tagging technology to determine depth preference at high tidal flow, when acoustic tag detection range biases results. Six double tagged sturgeon were released in Minas Basin in summer 2014 and 2015. These fish will provide archival records of sturgeon movement through Minas Passage.

5. Dadswell, Stokesbury, Logan-Chesney and Wirgin continue to analyze genetic samples from sturgeon tagged in Minas Basin, and Atlantic Sturgeon from rivers where populations have not been recorded but may contain spawning stocks (i.e. Avon River system, Whycocomagh Bay, Bras D'Or Lake, NS). VR2W's were deployed in the Saint John River by Litvak and HQP to monitor returning fish. Vitellogenin analysis was conducted on blood plasma samples to determine the sex of all tagged Atlantic sturgeon from the Saint John River. Habitat was described near potential spawning sites. Taylor has submitted a manuscript that addressed this goal.

6. Litvak and Taylor collaborated with Sheng and Ohashi (Dalhousie) to develop backward particle drift models to describe the location of over-winter sites. Habitat was described based on data collected and bathymetric information provided by the Canadian Hydrographic Service and Natural Resources Canada. Taylor has submitted a manuscript that addressed this goal.

7. Litvak and HQP monitored juvenile movements using stationary VR2W's and active tracking in the Saint John and Kennebecasis rivers. The extent of movements and aggregation areas were determined and stable isotope analysis was conducted on blood plasma samples of Atlantic sturgeon juveniles and shortnose sturgeon to determine overlap in foraging behavior. We tagged 12 juvenile Atlantic sturgeon in the spring of 2015. A new MSc student, Margaret Whitmore, joined the Litvak lab in July 2015 to continue working on this section of the project. In addition to tracking efforts, the Annual Lions Club Sturgeon Derby allowed for weights and measures to be taken on 93 sturgeon, two of which were juvenile Atlantics.

8. With the aid of local fishers, we caught and tagged one juvenile Atlantic sturgeon in the Petitcodiac River. Collaboration with the Fort Folly Habitat Recovery program has given us insight into viable fishing locations on the Petitcodiac River as well as connections with local fishers. Communication with AKOM is ongoing to determine the potential for tracking on the Miramichi River. We were able to tag one Atlantic sturgeon in the Petitcodiac in July 2015.

9. Taylor defended his MSc. thesis in December 2014. He has one published and two submitted manuscripts as a result of this research. Litvak was interviewed by CBC Radio on July 9, 2015, to discuss the status of Atlantic sturgeon and their fishery on the Saint John River. Litvak's lab takes the weights and measure for The Annual Lions Club Sturgeon Derby in October; this provides an opportunity for researchers to communicate with local fishers on the work being conducted as part of OTN.

c) Significant deviations

There has been no significant deviation from the original objectives or plans. However, the project continues to become more complex and multifaceted. Aside from additions listed in the last annual report we are using double tagging to determine movement in Minas Passage. We continue to work with Dr. Wirgin (NYU Langone Medical School, NY, USA) to determine stock composition and population specific movements of Atlantic Sturgeon. Also tagging of Striped bass, a population discovered in the Mira when searching for a Atlantic sturgeon population, as described in the last annual report, continues.

The OTN Canada Symposium in July 2015 allowed Litvak and Cooke to develop a new research program on the effect of angling and handling on sturgeon caught in the Saint John River. As part of this collaboration, Cooke sent two graduate students to Litvak's lab in September 2015 to assess physiological responses to angling stress. This research is currently being analyzed to establish best practices for recreational angling of sturgeon.

Further collaboration with OTN participant C. Taggart's PhD candidate Franziska Broell occurred in September 2015 examining the efficacy of accelerometry tags as a method for monitoring sturgeon behaviour.

d) Coordination and integration

Co-ordination of field work during the 2015 field season was the responsibility of each research unit (Minas Basin, Saint John Estuary, Mira River). Dadswell and Stokesbury worked together with their HQP personnel (Logan-Chesney, Buhariwalla, Stewart and Newell) to deploy receivers and tag fish in Minas Basin and in the Mira River. Litvak and his HQP personnel deployed receivers, tagged, sampled and tracked sturgeon in the Saint John, Kennebacasis and Petitcodiac Rivers. They also spent time on the Miramichi and Petitcodiac Rivers to promote future collaboration with First Nations working on those rivers. Technology and information transfer occurred both at the supervisor and graduate student level and is ongoing between lab personnel.

e) Scientific and/or engineering significance

In the last year we have determined these previously unknown facts:

Sturgeon specific:

- Growth rate of Atlantic sturgeon from the Saint John River population is faster than sturgeon in the Saint Lawrence River, but slower than sturgeon in the Kennebecasis River.

- The estimated size of the aggregation of Atlantic Sturgeon in Minas Basin during the summer of 2015 was 39,000 adults and sub-adults. This annual feeding aggregation draws heavily on populations from the Saint John River, Kennebecasis River and somewhat from US populations to the south (James and Hudson Rivers). Both adjusted Petersen and modified Schnabel population estimates determined were valid.

  The total adult population of the Saint John river was estimated at 18,000 individuals. Since Atlantic sturgeon do not spawn each year previous population sizes determined from the annual spawning run size are underestimates.

- Atlantic sturgeon often breach and this behaviour is captured in archival datasets. We are examining the relationship between this behaviour and physical variables.

Results of work conducted on the Petitcodiac River demonstrate its potential as a research location to monitor the movements of Atlantic sturgeon.

- While this river system is dynamic and difficult, it also means that assets deployed there will not be at risk for losses due to human activity—there are few people who use this system.

- Tracking work on the Saint John River identified a new potential aggregation site of Atlantic sturgeon.

Findings for other species as part of expanded sturgeon project:

- Modeled effects of predation on telemetry based estimates of survival for Atlantic salmon smolts and post-smolts (With J. Gibson, DFO and A. Halfyard, DAL).

  Discovered the over wintering site of Striped bass in the Mira River estuary and determined it's physical characteristics (temperature and salinity) and the winter behavior of the bass utilizing the site with C. Buhariwalla.

- Described residency and movement patters of Arctic char on Baffin Island with A. Spares DAL, and OTN Arctic.

  Determined movements and seasonal behavior of sea run brook trout in the Antigonish Harbor NS with A. Spares DAL

Engineering:

- Creation of a new attachment system to successfully attach Splash tags to Atlantic Sturgeon.

- Litvak's lab developed a novel attachment mechanism for accelerometry tags was designed and successfully implemented.

- A new collaboration between Litvak and VEMCO examining the potential for use of high frequency tags was initiated. The objective of this study is to be able to determine bearing of fish in real time.

f) Significance of research to the community/public

Results from the OTN sturgeon project provides stakeholder fishers and the community with information regarding status of local sturgeon populations and can contribute to recreational fisheries management/best practices.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Stokesbury working with Halfyard (Dal., OTN Atlantic) and Gibson (DFO) defining marine mortality of inner Bay of Fundy Atlantic salmon Smolts.

Stokesbury supervising, and Dadswell collaborating with Spares (Dal., OTN Arctic) to define coastal movements of Arctic Char and Sea Trout.

Litvak and his HQP collaborated with Cooke to develop best practices for recreational angling of sturgeon. They also collaborated with Taggart to determine the potential use of accelerometry tags for monitoring sturgeon behaviour.

b) Interaction/Outreach to Broader Community

Our project continues to provide proof of concept for the OTN. As one of the smaller projects we have greatly expanded our scientific reach while we have not deviated from our priorities. Our project continues to expand research collaborations and answer important questions relevant to OTNs original goals.

The OTN sturgeon project has had impacts at the regulatory level (i.e. Tidal Power effects, stock structure and abundance, sturgeon growth rate and periodicity of spawning for DFO). Also, knowledge and HQP transfer has occurred between the OTN sturgeon project, industry (i.e., Acadian Sturgeon and Caviar ltd.) and international partners (i.e., Matt Balazak, Virginia Commonwealth University, Kevin Stokesbury, U. Mass. and Ike Wirgin, NYU Langone Medical School, NY, USA).

The OTNC sturgeon project infrastructure in the Saint John River, Mira River and Minas Basin has also positively impacted other national and international projects as we have gained tracking information on striped bass and American eels (Broome and Redden, Acadia), great white sharks (Skomal, Mass. State Government, USA), Atlantic Salmon (Gibson, DFO), Arctic char and sea Trout (Spares, Dal. OTN Arctic) other Atlantic Sturgeon populations (Gayle Zydlewski U. Maine) and other Striped Bass populations in Cape Breton (Colin Buhariwalla, Acadia).

Drift net fishing has been conducted with local fishers in the Petitcodiac River. Connections with Fort Folly Habitat Recovery group have been made and they have agreed to provide labour and help with fishing and tagging Atlantic sturgeon on the Petiticodiac River in future efforts. The established collaborations are now in place and tagging and tracking of Atlantic sturgeon from the Petitcodiac River is organized to commence at the start of the upcoming field season.

Litvak has continued to conduct measurements at the Annual Lions Club Sturgeon Derby. This event provides an opportunity to discuss sturgeon conservation and current research with the public

9. Dissemination of information and results

a) Refereed journal articles (8 total) – accepted/published

Buhariwalla, C. F., MacMillan, J. L., Gregoire, M., M. J. Dadswell and M.J.W. Stokesbury, In Press. Population Characteristics of Striped Bass killed by cold shock during winter shutdown of a power plant in Nova Scotia. Northeastern Naturalist. Accepted 29 October 2015.

Gibson, A. J., F., Halfyard, E. A., Bradford, R. G., Stokesbury, M. J. W., and A. R. Redden. 2015. Effects of predation on telemetry-based survival estimates: insights from a study on endangered Atlantic salmon smolts. Canadian Journal of Fisheries and Aquatic Sciences, Accepted 14 December 2014.

Spares, A. D., Dadswell, M. J., Dickinson, M. P., and M. J. W. Stokesbury. 2015. A critical review of marine adaptability within the anadromous Salmonidae. Reviews in Fish Biology and Fisheries. Accepted 20 July 2015. DOI 10.1007/s11160-015-9392-z

Spares, A. D., Dadswell, M. J., MacMillan, J., Madden, R., O'Dor, R. K., and M. J. W. Stokesbury. 2014. Too fast to feed: an alternative life history for anadromous Brook Trout, Salvelinus fontinalis, overwintering within Antigonish Harbour, Nova Scotia, Canada. Journal of Fish Biology, 85:621-644.

Spares, A. D., Stokesbury, M. J. W., Dadswell, M. J, O'Dor, R. K., and T. A. Dick. 2015. Residency and movement patterns of Arctic Char, Salvelinus alpinus, relative to major estuaries. Journal of Fish Biology

Stewart, N. D., Dadswell, M. J., Leblanc, P., Bradford, R. G., Ceapa, C. and M. J. W. Stokesbury. 2015. Age and growth of Atlantic sturgeon from the Saint John River, New Brunswick, Canada. The North American Journal of Fisheries Management, 35:364-371.

Stokesbury, K. D. E., Stokesbury, M. J. W., Balazik, M. T., and M. J. Dadswell. 2014. Use of the SAFE index to evaluate the status of a summer aggregation of Atlantic sturgeon in Minas Basin, Canada and the implication of the index for the USA Endangered Species designation of Atlantic and shortnose sturgeons. Reviews in Fisheries Science and Aquaculture, 22:193-206.

Taylor, A.D. and M.K. Litvak. 2015. Quantifying a Manual Triangulation Technique for Aquatic Ultrasonic Telemetry. North American Journal of Fisheries Management, 35:5, 865-870, DOI: 10.1080/02755947.2015.1059909.

b) Refereed journal articles (4 total) – submitted

Beardsall, J. W., Stokesbury, M. J. W., and M. J. Dadswell. Submitted. Adult Atlantic sturgeon Acipenser oxyrinchus marine overwintering behaviour in Bay of Fundy: depth and temperature distributions. Journal of Applied Ichthyology(undergoing revision)

Stokesbury, M. J. W., McLean, M. F., Redden, A. R., Beardsall, J. W., Broome, J., Bates, D., and M. J. Dadswell. Submitted. Atlantic sturgeon spatial and depth distribution in Minas Passage, Nova Scotia: a region of future tidal power extraction. Transactions of the American Fisheries Society (Undergoing revision)

Taylor, A.D. and M.K. Litvak. Movement patterns and spawning sites of Atlantic sturgeon Acipenser oxyrinchus oxyrinchus in the Saint John River, New Brunswick, Canada. Transaction of the

American Fisheries Society. Submitted September 2 2015, in review (MS ID TAFS-2015-0155).

Wehrell, S. A., M. J. Dadswell, A. D. Spares, M. F. McLean, J. W. Beardsall, L. M. Logan-Chesney, G. S. Nau, C. Ceapa, A. M. Redden, and M. J. W. Stokesbury. Submitted. The annual feeding aggregation of Atlantic sturgeon(Acipenser oxyrinchus) in the inner Bay of Fundy: Population characteristics and local and long distance movements. Journal of Fish Biology (undergoing revision)

d) Conference presentations (8 total) – contributed

Ceapa, C, Dadswell, MJ, Curry, A, Bradford, R and Stokesbury, MJW. The Atlantic sturgeon stock in the Saint John River, New Brunswick Canada. Oral Presentation. Annual Meeting of the North American Paddlefish and Sturgeon Society, Oshkosh, Wisconsin, USA, 19-21 October, 2015.

Buhariwalla, C.F., M.J.W. Stokesbury, J.L. MacMillan, and M.J. Dadswell. 2015. Characteristics of Striped Bass killed at a power plant in Nova Scotia. Oral Presentation: 41st Annual meeting of the Atlantic International Chapter of the American Fisheries Society. September 2015. Cap-Pele, New Brunswick.

Logan-Chesney, L. M., Stokesbury, M. J. W. 2015. Atlantic sturgeon seasonality and breaching behaviour in Minas Basin, inner Bay of Fundy, Canada. American Fisheries Society (AFS) 145th Annual Meeting, Portland, Oregon. August 16-20, 2015. Poster presentation.

Buhariwalla, C.F., M.J.W. Stokesbury, and M.J. Dadswell. 2015. Movements of Striped Bass in the Mira River, Nova Scotia. Oral Presentation: 3rd International Conference on Fish Telemetry. July 2015. Halifax, Nova Scotia

Logan-Chesney, L. M., Stokesbury, M. J. W. 2015. Atlantic sturgeon seasonality and breaching behaviour in Minas Basin, inner Bay of Fundy, Canada. 3rd International Conference on Fish Telemetry (ICFT), Halifax, Nova Scotia. July 13-17, 2015. Poster presentation.

Logan-Chesney, L. M., Stokesbury, M. J. W. Atlantic sturgeon seasonality and breaching behaviour in Minas Basin, inner Bay of Fundy, Canada. Science Atlantic: Fisheries and Aquaculture, Moncton, New Brunswick. March 6-8, 2015. Oral presentation.

Logan-Chesney, L. M., Stokesbury, M. J. W. 2015. Atlantic sturgeon seasonality and breaching behaviour in Minas Basin, inner Bay of Fundy, Canada. Acadia Grad Student Association (AGSA) Conference, Wolfville, Nova Scotia. February 27-28, 2015. Oral presentation.

McLean, M.F., Dadswell, M.J., Stokesbury, M.J. 2015. All Things Acipenseridae. U.S. Fish and Wildlife Abernathy Fish and Technology Center Seminar Series. Longview, Washington, USA. February 26, 2015.

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

Litvak, M.K. Invited interview. CBC Radio. July 9, 2015. Atlantic sturgeon status.

b) Invited or contributed open-to-public presentation/contribution

Taylor, A.D. December 5, 2014. MSc Thesis defense. Movement patterns, habitat use, and seasonal distribution of Atlantic sturgeon, Acipenser oxyrinchus, from the Saint John River, New Brunswick, Canada.

d) Invited or contributed presentation/contribution at a seminar series

Stokesbury, M.J.W. 2015. Western Atlantic Bluefin Tuna Stock Structure, Migration, and a Changing Canadian Fishery. Technical University of Denmark, Copenhagen, Denmark, 23 April, 2015.

Stokesbury, M.J.W. 2015. Western Atlantic Bluefin Tuna Stock Structure, Migration, and a Changing Canadian Fishery. Technical University of Denmark, Silkeborge, Denmark, 21 April, 2015.

f) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, conference proceedings, as well as a contribution to a larger piece of work in any of the former (Note: please provide web links to the reports where possible)

Dadswell, MJ. 2015. Comments on the COSEWIC 2011 assessment and status report for Atlantic sturgeon (Acipenser oxyrinchus Mitchill, 1815) for the St. Lawrence and Maritimes DU's and its role in the 2015 status assessment for the Species at Risk Act (SARA). Submitted to the SARA Assessment, Ottawa, Ontario, Feb 28, 2015. doi 10.13140/RG. 2.1.4392.1440

Stokesbury, MJW. 2015. Comments on the COSEWIC 2011 assessment and status report for Atlantic sturgeon for the St. Lawrence and Maritimes DU's and its role in the 2015 status assessment for the Species at Risk Act (SARA). Submitted to the SARA Assessment, Ottawa, Ontario, Feb 28, 2015.

Litvak, M.K. 2015.Comments on the COSEWIC 2011 assessment and status report for Atlantic sturgeon for the St. Lawrence and Maritimes DU's and its role in the 2015 status assessment for the Species at Risk Act (SARA). Submitted to the SARA Assessment, Ottawa, Ontario, Feb 28, 2015.

COSEWIC 2015. COSEWIC Assessment and Update Status Report on the Shortnose Sturgeon Acipenser brevirostrum in Canada. Written by Litvak.

h) Data deposition to OTN Data Centre

All OTN sturgeon project tracking data is up to date in the OTN data centre.

m) Anything else that isn't a primary publication that has you communicating with others

* Stokesbury Lab: http://coastalecology.acadiau.ca/

* Litvak Lab: http://sites.google.com/site/litvaklabsite/Home

n) Leveraging your research/funds in order to make a new contribution to another initiative

- Expansion to Mira and other Maritime Rivers

- Contribution to OEER tidal power impacts research

Winter Fish kill in the discharge at the Trenton Power Plant, Pictou Nova Scotia

r) Baseline measures (e.g. reference for change), empirical relations (e.g. rates and states), or mapping products (e.g. range expansion or contraction) especially if of use to other scientists and the organizations listed above

Presence of a spawning population of striped bass in the Mira River, Cap Breton. In overwinter site for striped bass in Canada in the Mira River estuary.

s) Other (e.g., checklist, barcode, CTD casts, and/or Glider runs, or anything else that does not fall within one of the above categories)

The OTNC sturgeon project interacts with the public on several fronts. Commercial fishers in the Minas Basin belonging to the High Current Fishermen's Association are active participants in all tagging and receiver deployment planning. Commercial fishers for Atlantic sturgeon in the Saint John River help in the Saint John River tagging by reporting captures. In both areas the commercial fishers that are involved in the project are active in their fishing and residential communities and help inform the public of the project goals and progress. Also, Stokesbury has delivered information to Gulf Nova Scotia tuna fishers on tracking of Atlantic bluefin tuna, using acoustic tags, through OTN lines (i.e., Cabot Straight, Straight of Belle Isle, Halifax Line). Buhariwalla and Dadswell have developed extensive contacts with striped bass anglers in Cape Breton and continue to answer their questions and provide new information on bass.

The public are informed of our goal through several web applications. Stokesbury and Litvak have websites that are accessed by students and the public. Many potential students become interested in our projects through this outlet and we regularly receive emails enquiring about positions as students or technicians to work with our project.

11. Collaborations with industrial and government partners

a) Partners

Government - Fisheries and Oceans, Transport Canada, Parks Canada and their scientific, statistical and management branches; Offshore Energy Research Association

The OTNC sturgeon project provides information on animal behaviour to the Offshore Energy Research Association. OERA is an arms-length provincial government body that provincial that invests in environmental research for ocean energy. Stokesbury is a member of the OERA Environmental Monitoring Advisory Committee, which has 3-4 m meetings a year to report on progress of research on possible impacts of tidal power.

Rod Bradford of Fisheries and Oceans Canada is involved in our sturgeon work as he is responsible for Anadromous species of concern. Bradford meets with Stokesbury regularly and with Litvak when possible. Bradford and Fisheries and Oceans collaborated with Stokesbury on OTNC sturgeon presentation at the DFO SARA evaluations for Atlantic Sturgeon.

Natural Resources Canada and the Canadian Hydrographic Service provided bathymetric data to Litvak and HQP for habitat analysis.

Industry – Acadian Sturgeon and Caviar Inc. on the Saint John River, New Brunswick

Stokesbury and Dadswell worked with Dr. Cornel Ceapa of Acadian Sturgeon and Caviar Inc., and Dr. Rod Bradford of DFO on an OTN and NSERC Engage funded research project to determine the growth rate and total adult population size of Atlantic Sturgeon from the Saint John River stock.

b) Contributions

Name of supporting organization: **CFI**	**Year 6** (2015)
Cash contributions to direct costs of research	62.5 k
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	62.5 k
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Acadia University**	**Year 6** (2015)
Cash contributions to direct costs of research	12.5
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	2.0
4) Field work logistics	4.0
5) Provision of services	1.0
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	6.0
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	25.5
Is this new funding (acquired during this reporting period)?	no

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.7

2. Project Title: Grey seals (*Halichoreus grypus*) as bioprobes: predicting impacts on their ecosystems

3. Project Leaders: Sara Iverson (Dalhousie U), Don Bowen (DFO-Bedford Inst, Dalhousie U), Joanna Mills Flemming (Dalhousie U)

Other OTN Canada participants: K. Fennel, J. Sheng, T. Ross, I. Fleming

Collaborators: Mike Hammill (DFO-Gulf region), Luke Comeau (DFO-NB), Doug Swain (DFO-Gulf region), Fred Whoriskey (OTN), D. Webber (Vemco), B. McConnell (Sea Mammal Research Unit)

4. Public summary of report

Between December 2014 and January 2015, 13 of the 16 VMT and satellite transmitters deployed on grey seals on Sable Island in June 2014 were recovered, in addition to data from the five Bluetooth units deployed in the southern Gulf of St. Lawrence, July 2014. The two Maritime Biologger accelerometers deployed on male grey seals on Sable Island were not recovered, but the Wildlife Computers GPS-accelerometer tag that was carried by a female seal was recovered with 66 days of data. A preliminary examination of the data suggests that foraging bouts, amongst other behaviours, can be discerned and supports continuation of the accelerometer component of the project. Grey seals deployed in the Gulf remained very close to their deployment site (Isles de la Madeleine) suggesting a local abundance of prey throughout much of the year. The majority of the detection data from the VMT units (93%) were due to 19 of the 21 seals detecting other VMT-tagged seals. Of the remaining detections, 77 were from sentinel moored tags and 49 were from six OTN tagged marine species from seven OTN projects. Seals deployed at Sable Island detected Atlantic cod, salmon, snow crab, bluefin tuna and blue shark, while those deployed in the Gulf detected Atlantic cod and lobster. A single male grey seal from Sable Island interacted with two bluefin tuna during mid-October on the Eastern Scotian Shelf. In June 2015, 15 more grey seals from Sable Island were each deployed with a VMT, satellite transmitter, accelerometer and inertial tag (Maritime Biologgers). Given the improved attachment method used we expect that data from the accerelometer and inertial tags will enable us to identify episodes of prey capture to determine whether grey seals are foraging during encounters with tagged fish and help inform state-space behavioural switching models. With assistance from DFO and local fishermen, five additional grey seals were deployed with a Bluetooth VMT and satellite transmitter at the Magdalen Islands in July 2015, and cod were tagged (79 on the Scotian Shelf and 100 in the southern Gulf) in May. MSc student Benia Nowak joined the bioprobe project to examine the influence of oceanography on grey seal movement and habitat use. This project is providing important information on the ecology, species interactions, and role of grey seals in the NW Atlantic ecosystem.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Damian Lidgard	RA	80	80	1 Jan 2010	31 Dec 2016
Research Topic: Encounters between grey seals and their prey and at-sea social interactions amongst grey seals					
Shelley Lang	RA	25	0	1 Jan 2010	25 Sep 2015
Research Topic: Combining dietary data and grey seal habitat use					
Benia Nowak	MSc	100	100	4 May 2015	6 April 2017
Research Topic: Examing the influence of oceanographic features on the movement and habitat use of grey seals					
Lindsay Randell	BSc	40	0	1 April 2015	Dec 2016
Research Topic: Using acoustic telemetry to examine movement patterns of cod					

b) Role, activities, and opportunities for training

Technical staff were responsible for analysis of grey seal and prey samples for diet analyses, organization and upkeep of the prey database, and support of field work.

6. Progress towards objectives/milestones

a) Overall objectives

a) continue investigating the spatial and temporal encounters between grey seals and several important prey species by using newly developed visualization tools

b) enhance VMTs so that they transmit archived data in near real time to Argos via a Bluetooth connection

c) test the hypothesis that grey seals condition their movement on the physical oceanography to reduce the energetic cost of foraging,

d) analyze seal-seal encounters (acoustic detections) to better understand grey seal foraging behaviour.

b) Progress

Objectives a, b and d): Between December 2014 and January 2015 we recovered 13 of the 16 VMT and satellite transmitters deployed on grey seals on Sable Island in June 2014. Of these, one female had been deployed with a Wildlife Computers accelerometer tag which was successfully retrieved upon her return to Sable Island. Initial inspection of these data suggests that foraging, in addition to other behaviours, can be identified. Two male grey seals had also been deployed with an accelerometer (Maritime Biologger) on the lower jaw but both seals lost the tag. The aim of deploying accelerometers is to record the movement of the head and body to better understand what seals are doing when the VMT detects tagged fish, or when the seal engages in Area-Restricted Search (ARS) behaviour as indicated by the GPS data; our current data from the Hidden Markov model suggests seals are often not engaged in foraging (ARS) behaviour when in the presence of tagged fish but this requires confirmation. Thus in June 2015, 15 adult grey seals on Sable Island were deployed with a Maritime Biologger accelerometer

on the head and intertial tag on the back, in addition to a satellite transmitter and VMT. To calibrate the data retrieved from the accelerometers, in October 2015 two grey seals will be deployed with a customised camera system developed by CATS, in addition to the same instruments deployed on the other 15 seals. The hope is to use the video footage from the camera to correlate the behaviour of the seal with the accelerometer and inertial data. Similar to the previous year, and unlike the grey seals on Sable Island, four of the five grey seals deployed at the Magdalen Islands remained in a small home range suggesting an abundance of prey close to their haul-out sites. The fifth seal travelled to Saint Pierre and Miquelon where it spent much of the summer before travelling to Sable Island for the breeding season.

Similar to previous years, the VMTs recorded a large number of detections (n=2,206) the majority of which (93%) were seal-seal detections. The remaining detections were from sentinel moored tags (n=77) and six different OTN tagged marine species (n=49) from seven OTN projects. Seals deployed at Sable Island detected Atlantic cod, salmon, snow crab, bluefin tuna and blue shark, while those deployed in the Gulf detected Atlantic cod and lobster, the latter having been deployed close to where the seals were tagged. A single male grey seal from Sable Island interacted with two bluefin tuna during mid- October on the Eastern Scotian Shelf, although detections were few. In July 2015, with assistance from DFO Quebec and local fishermen, five grey seals were deployed with a Bluetooth VMT and satellite transmitter at the Magdalen Islands; these units should continue to transmit through to spring 2016. In May 2014 Sean Smith (DFO Maritimes) tagged another 100 Atlantic cod with V13 tags on the Eastern Scotian Shelf, and another 70 were deployed in June 2015 in the southern Gulf of St. Lawrence through DFO Gulf.

L. Randell, BSc student, joined OTN in April 2015 as a Dalhousie University experiential student supervised by D. Lidgard. To date tasks have included assisting with organising equipment for the June Sable Island deployment trip, and conducting exploratory analyses on Atlantic cod detection data collected by the Halifax and Cape Breton acoustic lines using tools developed by OTN Data Management and the R package, V-Track.

Please see 4.8 for progress on the development of visualization tools.

Objective c: In May 2015 Benia Nowak joined the bioprobe project as a Masters student who's thesis work will incorporate the oceanographic data collected by the satellite transmitters along with data on seal movements and habitat use into oceanographic models.

Objective d: GPS data collected by each seal between 2009 and 2014 have been analysed using TLoCOH, a movement analysis software. TLoCoH uses both time and space to calculate home range size and analyse movement and habitat use data. Given that the satellite transmitters record GPS data every 15 minutes, the analysis will be at a fine-scale and allow a better understanding of how grey seals are using space for foraging and their habitat preferences.

Milestone Table of planned output:

D Bowen and D Lidgard are collaborating on a paper examining the role of marine mammals in marine ecosystems; Submission - summer 2016

D Bowen, S Lang, D Lidgard and S Iverson are collaborating on a paper that will link the diets of grey seals, based on fatty acids and stable isotopes, with foraging patterns; Submission - fall 2016

D Lidgard and D Bowen are collaborating with M Auger-Méthé, I Jonsen and J Mills-Flemming on the use of the Template Model Builder to model the movement of grey seals at sea; Submission - February 2016

'Using bioprobes to examine predator-prey interactions in a marine system' (with D Bowen, S Iverson, Ian Jonsen); Submission - July 2016

'Animal movement and space-use in terrestrial and marine ecosystems' (with M Auger-Methe) Submission - May 2016;

Review of animal accelerometry (with F. Broell, C. Taggart; Submission - fall 2016

c) Significant deviations

None, other than exploiting the novel opportunity to deploy animal-borne cameras (see (e) below) on 2 seals.

d) Coordination and integration

As in previous years, monthly meetings have continued with all co-investigators and HQP involved in both the bioprobe project (4.7) and the data visualization project (4.8) to develop collaborations and ensure all parties involved are kept up-to-date.

S. Smith and D. Bowen (DFO, Maritime Region) organized the tagging of cod on the Eastern Scotian Shelf in May 2015, while S. Smith conducted the surgery to implant the tags. D. Swain, L. Comeau and S. Leblanc (DFO, Gulf Region) organized the tagging of cod in the Gulf of St. Lawrence in June 2015, and L. Comeau and S. Leblanc conducted the surgery.

Collaboration between Vemco, the Sea Mammal Research Unit in Scotland and OTN has continued through the deployment of Bluetooth VMTs and satellite transmitters in the southern Gulf of St. Lawrence. As in the previous year, five Bluetooth VMTs and GPS units were deployed on grey seals at the Magdalen Islands in July 2015 with logistical support from Mike Hammill (DFO, Quebec) and local fishermen.

In June 2015 we deployed 15 accelerometers and 15 inertial tags on female and male grey seals on Sable Island, through collaboration with Maritime Biologgers (developed by OTN HQP, project 4.3). Upon retrieval of the units in Dec 2015/Jan 2016, Maritime Biologgers will assist with the analysis of the data and determination of whether grey seals were foraging during encounters with tagged fish. These data will also contribute toward understanding the behaviour of seals during periods of travel and area-restrictive search (ARS). To calibrate these data, two CATS customised cameras were deployed on two adult female grey seals along with the other instruments.

e) Scientific and/or engineering significance

Since the first use of the Bluetooth-linked VMT and satellite transmitters in 2012, 18 grey seals have now been deployed with this technology in the southern Gulf, thus broadening our geographical sampling area and providing a more representative sample of seal-seal and seal-fish encounters. It is clear that the behaviour of the grey seals deployed in the southern Gulf exhibit restricted movements,

with individuals staying close to their site of deployment. This suggests an abundance of prey close to haul-out sites. In June 2015 each of the 15 grey seals captured on Sable Island were deployed with a Maritime Biologger (Halifax, Nova Scotia) accelerometer and inertial tag to examine fine-scale head and body movements during encounters with tagged fish and ARS behaviour. These units were custom built by Maritime Biologgers thus contributing toward the company's research and development achievements.

In a similar vein, animal-borne cameras custom designed by CATS (Australia) were deployed on two grey seals on Sable Island, in addition to the same instruments deployed on the other 15 seals. The intention is to use the video footage from the camera to correlate the behaviour of the seal with the data from the accelerometer and inertial tags and confirm bouts of foraging behaviour. These data will help us better understand the foraging behaviour of grey seals and determine whether seals are predating on fish during encounters with tagged fish, as well as contribute toward product development for CATS.

f) Significance of research to the community/public

High rates of mortality from unknown causes have contributed toward the dramatic decline in Western Atlantic salmon stocks and failure of Atlantic cod stocks to recover from overfishing. Grey seals are considered to be a potential source of mortality for both species, however despite calls for a cull in the southern Gulf of St. Lawrence the importance of cod and salmon in the grey seal diet is not well understood. In addition to contributing toward our general knowledge of grey seal ecology and their importance to the marine ecosystem, this project will provide a better understanding of the importance of cod and salmon to grey seals.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

The following collaborations from the previous year are continuing: D Bowen and D Lidgard are collaborating on a paper examining the role of marine mammals in marine ecosystems; D Bowen, S Lang, D Lidgard and S Iverson are collaborating on a paper that will link the diets of grey seals, based on fatty acids and stable isotopes, with foraging patterns; D Lidgard and D Bowen are collaborating with M Auger-Méthé, I Jonsen and J Mills-Flemming on the use of the Template Model Builder to model the movement of grey seals at sea. D Lidgard is a member of ideasOTN and is involved in three research papers: 'Using bioprobes to examine predator-prey interactions in a marine system' (with D Bowen, S Iverson, Ian Jonsen), 'Animal movement and space-use in terrestrial and marine ecosystems' (with M Auger-Methe) and 'Review of animal accelerometry (with F. Broell, C. Taggart)'.

As noted above, monthly meetings have continued with all co-investigators and HQP involved in the bioprobe and data visualization projects to develop collaborations and ensure all parties involved are kept up-to-date.

b) Interaction/Outreach to Broader Community

D Lidgard gave three presentations to young students at local schools and organisations (Bedford Academy, SuperNova Dalhousie University and Thrive Education) on the grey seal research on Sable Island and the work of OTN.

D Lidgard gave presentations to students attending the Dalhousie University Seaside class 'Field Studies of Marine Mammals', 'Marine Mammalogy' and 'Biologging in Ecology' on grey seal research on Sable Island and OTN's use of telemetry to study predator-prey interactions.

S Iverson presented the grey seal work for the Graduate Seminar Series at the Great Lakes Institute for Environmental Research.

D Bowen and D Lidgard initiated a collaboration with Wendy Puryear (Biological Engineering, MIT) through sharing grey seal movement data to contribute to her study on the ecology of influenza in Western Atlantic grey seals.

S Iverson presented the bioprobe research to the new first year Ocean Sciences Class at Dalhousie.

S Iverson presents on OTN very frequently throughout the year and alwys features the bioprobe project in these talks.

D Lidgard provided grey seal GPS data for the DFO White Hake Recovery Assessment and Herring Stock Assessment to provide an estimate of grey seal predation on hake and herring in various NAFO regions.

In collaboration with Jarrett Corke (WWF), D Lidgard submitted an entry to the international competition 'Oceans180' which involved creating a 3-minute video of the research results from the use of VMTs deployed on grey seals to examine predator-prey interactions with Atlantic cod and salmon, designed for viewing by Grade 7 - 8 students. D Lidgard is currerntly in the process of creating a second video for the same competition which will highlight the use of bluetooth technology to remotely collect data on encounters between grey seals and fish.

D Lidgard is in discussion with Graham Caswell (Museun of Natural History, Halifax) on the use of the museum's 'Science on a Sphere' to display grey seal movement paths as a means to highlight the work of OTN to the general public.

Co-PIs, HQP, and many collaborators, attended the joint International Fish Telemetry Conference and 5th Annual OTN Canada-wide Symposium, in Halifax in July 2015. D. Lidgard gave a presentation at the conference.

9. Dissemination of information and results

a) Refereed journal articles (1 total) – accepted/published

Baker LL, Flemming JEM, Jonsen ID, Lidgard DC, Iverson SJ, Bowen WD (2015) A novel approach to quantifying the spatiotemporal behavior of instrumented grey seals used to sample the environment. Movement Ecology, Movement Ecology, 3(1): 20. doi: 10.1186/s40462-015-0047-4. eCollection 2015.

c) Conference presentations (1 total) – invited

Iverson SJ (2015) What top predators can tell us about ocean ecosystems. Graduate Seminar Series, Great Lakes Institute for Environmental Research, Sept 2015, Windsor, ON

d) Conference presentations (1 total) – contributed

Lidgard DC, Bowen WD, Iverson SJ (2015) Using acoustics to elucidate the nature of marine predator-prey interactions. International Fish Telemetry Conference, July 2015, Halifax

10. Other contributions and deliverables

c) Invited or contributed open-to-public presentation/contribution

D Lidgard and D Bowen contributed papers to the Friends of Sable Island Society conference "Science and History of Sable Island", entitled “Using the Sable Island grey seal as a biological probe” and "Ecological footprints of grey seals on and off Sable Island "

f) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, conference proceedings, as well as a contribution to a larger piece of work in any of the former (Note: please provide web links to the reports where possible)

D Lidgard provided grey seal GPS data for the DFO White Hake Recovery Assessment and Herring Stock Assessment to provide an estimate of grey seal predation on hake and herring in various NAFO regions.

g) Data deposition to an agency/database (e.g., MEDS, GenBank, OBIS)

GPS grey seal data from 2010 were deposited in the data repository Movebank

h) Data deposition to OTN Data Centre

All 2015 data arising from the grey seal bioprobe instrument deployments and the acoustic tagging of Atlantic cod were deposited in the OTN Data Center.

k) Reference or training tools/materials (e.g handbook or guide)

D Lidgard is assisting WWF with reviewing the marine mammal section in their Sea ID app for smartphones.

m) Anything else that isn't a primary publication that has you communicating with others

D Lidgard is in discussion with Graham Caswell (Museun of Natural History, Halifax) on the use of the museum's 'Science on a Sphere' to display grey seal movement paths as a means to highlight the work of OTN to the general public.

D Lidgard collaborated with Jarrett Corke (WWF), to create a 3-minute video of the research results from the use of VMTs deployed on grey seals to examine predator-prey interactions with Atlantic cod and salmon, designed for viewing by Grade 7 - 8 students. D Lidgard is currerntly in the process of creating a second video for the same competition which will highlight the use of bluetooth technology to remotely collect data on encounters between grey seals and fish.

p) A new technology, method, protocol, measure, analytical technique, algorithm, operational or numerical model, or predictive tool. Include the validation of any of the former and their practical application

Fifteen grey seals on Sable Island were deployed with an accelerometer and inertial tag in June 2015, all of which were designed and built by Maritime Biologgers, Halifax, a company that wes developed by OTN HQP. These data will help us better understand the foraging behaviour of grey seals and determine whether seals are predating on prey during encounters with tagged fish. In October 2015, two female grey seals were deployed with a Maritime Biologger accelerometer and inertial tag, in addition to a custom designed camera (CATS, Australia). The camera will provide behavioural footage of the seal during encounters with prey which can be used to calibrate the data from the accelerometer and inertial tag.

11. Collaborations with industrial and government partners

a) Partners

The Department of Fisheries and Oceans, Canada (DFO Maritimes, Quebec and Gulf) continues to be integral for the deployment of telemetry and data-logging instruments on grey seals and transmitter tags on Atlantic cod. DFO provides the basic logistics and equipment for conducting fieldwork on Sable Island and deployment of the VMT and GPS tags. Their logistical and knowledge support was particularly invaluable for the deployment of the Bluetooth-linked VMTs and satellite transmitters on the Magdalen Islands, southern Gulf of St. Lawrence in July 2015. DFO is also integral to the deployment of transmitters on Atlantic cod on the Eastern Scotian Shelf and in the souther Gulf, providing the boat, crew and experienced personnel for conducting surgery on live fish.

VEMCO continues to provide the necessary technical support and product development for both the standard VMT and Bluetooth-linked VMT.

The Sea Mammal Research Unit, Scotland also have been invaluable in developing the Bluetooth link for the VMT and an algorithm for the compression of data for transmission of detection data via satellite.

Maritime Biologgers custom built seventeen accelerometer and inertial tags for deployment on grey seals in June and October 2015. Maritime Biologgers will work with D. Lidgard to analyse the data.

Two cameras were custom built by CATS, Australia for providing behavioural footage of grey seals for calibrating the data from the acclerometer and inertial tags.

b) Contributions

Name of supporting organization: **CFI**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	237000
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	6000
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	45000
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	51000
Is this new funding (acquired during this reporting period)?	no

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.8

2. Project Title: Visualization and modelling of complex marine observations

3. Project Leaders: Joanna Mills Flemming (Dalhousie U)

Other OTN Canada participants: D. Bowen, S. Iverson, C. Taggart, G. Crossin, I. Fleming, J. Dodson, S. Cooke, A. Fisk

Collaborators: Simon Bonner (Western University), Chris Field (Dalhousie U), Aaron McNeil (Australian Institute of Marine Science), Wayne Olford (U Waterloo), Tim Stone (Vemco), Dale Webber (Vemco), Ian Jonsen (Macquarie University), Duncan Murdoch (Western University), Anders Neilsen and Christoffer Moesgaard Albertsen (both from the Technical University of Denmark)

4. Public summary of report

The 'Visualization and Modelling of Complex Marine Observations' cross-cutting activity has had another very successful year. It started with PhD candidate Elias Krainski from the Department of Mathematical Sciences at the Norwegian University of Science and Technology visiting Dalhousie U from January 11th to 18th. He worked directly with PhD candidates Stuart Carson (SC) and Aurelie Consandey Godin (ACG) to assist them with modeling their complex marine datasets using the R-INLA package. Our second annual workshop (titled 'Visualizing and Analyzing Telemetry Data in R') was held June 11th and 12th in the Steele Ocean Sciences Building at Dalhousie U. This workshop was at capacity with more than 20 participants and proved extremely helpful in both advancing our knowledge of the R package Template Model Builder (TMB) and providing guidance with visualization tools. We then hosted a three hour workshop on July 17th (titled 'Modelling of Animal Movement') as part of the 3rd International Conference on Fish Telemetry (ICFT) in Halifax. This too was at capacity with over 30 participants. Our Gitlab OTN Statistical Modelling Group continues to be very active due mostly to the hard work of Marie Auger-Méthé (MAM) who was also instrumental to the success of our workshops. With the submission of a journal article titled 'Density Dependent Habitat Selection of Atlantic Cod and Remnant Sub-Populations as Revealed by a Spatio-Temporal Model', SC's thesis is well underway. MSc candidate Kim Whoriskey (KW) co-authored an article (now in press with Ecology) which is the first documented use of TMB for the rapid fitting of non-Gaussian state-space models (a popular approach for movement ecologists) to Argos satellite telemetry data. JMF continues to oversee all aspects of this cross-cutting activity while also serving on OTN's International Scientific Advisory Committee (ISAC) and International Data Management Committee (IDMC).

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Stuart Carson	PhD	100	100	1 Jan 2012	1 Mar 2016
Research Topic/current employment (if no longer OTNC HQP): Getting off the track: spatio-temporal statistical methods					

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
for evaluating at sea acoustic tag data					
Marie Auger-Méthé	PDF	100	100	1 Aug 2014	31 Dec 2016
Research Topic: Efficient and Robust State-Space Models for Animal Movement Data					
Kim Whoriskey	MSc	100	100	1 Sept 2014	31 Aug 2016
Research Topic: Advancements to Behaviour Identification from Marine Animal Tracks through Template Model Builder.					

b) Role, activities, and opportunities for training

SC, who started his PhD in 2012, has finishing in sight. In April, with Nancy Shackell (from DFO) and JMF, he submitted an article 'Density Dependent Habitat Selection of Atlantic Cod and Remnant Sub-Populations as revealed by a Spatio-Temporal Model' to Ecological Applications for their consideration. Shortly thereafter, Dalhousie U played host to both the Statistical Society of Canada (SSC) Annual Meetings and to the 3rd ICFT. SC presented a talk and a poster respectively at these two events. SC is now submerged in thesis writing with the goal of finishing this year.

MAM started her PDF with OTN on August 1st 2014. MAM's main role is to develop improved methods for fitting animal movement models to OTN related data. In particular, Marie is developing robust and efficient tools that allow one to fit complex models to such data. She is currently working in close collaboration with multiple OTN Canada participants (e.g. Glenn Crossin, Eduardo Martins, Nigel Hussey) as well as Rob Harcourt who is the Chair of the OTN ISAC. She has been invited to give talks at three conferences and has recently submitted a manuscript describing the pitfalls of using state-space models. She is also finishing up a manuscript describing new approaches for fitting state-space models to marine data. She is the co-chair of ideasOTN, a group that foster synthesis activities and collaboration across the network. To help disseminate the use of the tools she and others are developing, she gave a graduate short class, and posted most materials and tools online via the OTN GitLab statistical modeling group account (https://gitlab.oceantrack.org/groups/otn-statistical-modelling-group). She is also heavily involved in a variety of other OTN activities, including reviewing abstracts and serving as a session moderator for the conference organized by OTN.

Kim started her MSc under the supervision of JMF on September 1st 2014, and has continued her MSc training this year with graduate level statistics courses and by participating in various workshops. She helped organize and presented at both of our workshops and also attended the second annual Canadian Statistical Sciences Institute (CANSSI) Workshop for Team Leader JMF's Collaborative Research Team Project 'Advancements to State-Space Models for Fisheries Science'. Kim presented her research at the 43rd Annual Meetings of the SSC. Finally, she has significantly advanced techniques for data visualization of marine telemetry data by working closely with Jon Pye (OTN Global employee) to explore new visualization methods and with Duncan Murdoch (Western U) to develop visualization methods specifically using his R-package rgl.

6. Progress towards objectives/milestones

a) Overall objectives

This cross-cutting activity will make certain that the visualization and modelling techniques for complex marine observations as used (or envisioned) by various OTN Canada participants and HQP are optimal for dealing with OTN (and other) tracking data and the ensuing large complex data sets that arise as we

attempt to link environmental features with animal movements. In addition, it will ensure that observing technologies (acoustic transmitters and receivers, tracking devices, environmental sensors) and accompanying modeling techniques are properly integrated into the network (as well as globally).

b) Progress

As stated in our original proposal, our first objective was to organize an annual workshop to bring together OTN HQP and experts in statistical modelling and data visualization so as to develop the tools necessary to effectively analyze OTN related data in order to answer important scientific questions. Following a successful inaugural workshop, a second equally successful workshop took place June 11-12 again at Dalhousie U in the Steele Ocean Science Building.

Our second objective was to create a repository of documented shared code and freely available software for OTN researchers as well as the broader scientific community. We now have the OTN Statistical Modelling Group on GitLab. MAM maintains this open and public account on the GitLab which serves as a repository for tools (many of which were taught in the workshops) and documentation to facilitate using TMB for the efficent and robust fitting of state-space models. This account currently has 6 members and 8 projects as well as multiple closed and private repositories that track the code used in all OTN research projects for which she is leading the analysis. Once a research article associated with these projects is published, the code repository is made open to the public and a link added into the published article, thus allowing all readers access to the code. KW works similarly in this regard.

Our third objective was to facilitate the exchange of HQP between OTN arenas, and internationally as resources permit, in order to foster stronger collaboration on modelling and visualization tools useful in many OTN projects. The participants in our two annual workshops as well as those that attended our workshop at the 3rd ICFT are clear evidence of the success that we have had in not only making it possible for HQP to attend but also in attracting researchers interesting in learning about our tools from all over the world. See Section 8.a) for further details.

Milestone table of future output/dissemination:

K. Whoriskey, MSc Thesis, Summer 2016.

S. Carson, PhD Thesis, Summer 2016.

Marie Auger-Méthé, C. Field, C.M. Albertsen, A.E. Derocher, M.A. Lewis, I.D. Jonsen, J.E. Mills Flemming. State-space models' dirty little secrets: even simple linear Gaussian models can have estimation problems. Submitted to Scientific Reports.

R.J. Lennox, I. Mayer, T. B. Havn, M. R. Johansen, K. Whoriskey, S. J. Cooke, E. B. Thorstad, and I. Uglem. Testing air exposure thresholds for European grayling Thymallus thymallus in a catch-and-release setting. Submitted to Boreal Environmental Research.

Stuart Carson, N. Shackell, J. Mills Flemming. Density Dependent Habitat Selection of Atlantic Cod and remnant sub-populations as revealed by a Spatio-Temporal Model. Submitted to Plos One.

S. Carson, S. Lang, D Bowen, J Mills Flemming. Spatial-point process models of habitat use in a large marine predator: effects of prey and population density, in progress.

K Whoriskey, M. Auger-Méthé, C. M. Albertsen, and J. Mills Flemming. A Hidden Markov Movement Model for rapidly identifying behavioural states from animal tracks, in progress.

K Whoriskey, D Bowen and J. Mills Flemming, Post-breeding foraging tactics of female grey seals in contrasting ecosystems: Comparison of a coastal and offshore breeding colony, in progress.

K Whoriskey, S Cooke, M. Auger- Méthé, E. Martins, L Gutowsky, V. Nguyen, J Mills Flemming. Review: statistical methods for telemetry, in progress.

M. Auger-Méthé, G. Crossin, I. Derocher, C. Albertsen, J.E. Mills Flemming. Template Model Builder: a promising tool to model the movement of marine animals, in progress.

c) Significant deviations

Our second workshop was held in June rather than in November or February as originally proposed.

Initial collaborators Keith Thompson, Steven Bograd, Mike Dowd, Jeremy Goldbogen and Martin Pedersen should be removed as they have not been involved this year and we do not anticipicate collaborating with then in Year 7. Duncan Murdoch (Western University), Anders Neilsen and Christoffer Moesgaard Albertsen (both from the Technical University of Denmark) should all be added to the list of collaborators.

d) Coordination and integration

Our second annual workshop had 22 participants including various HQP (MAM, KW, Emily-Ann Butler, Steve Kessel, Lee Gutowsky, Melanie Beguer, Nigel Hussey, Dave Yurkowski, Eduardo Martins, SC, Benia Nowak) representing OTN Canada participants D. Bowen, G. Crossin, S. Cooke, J. Dodson, A. Fisk, JMF, S. Iverson and C. Taggart along with HQP (Sarah Gutowsky, ACG) of Dalhousie U faculty members Marty Leonard and Boris Worm, and Dalhousie U faculty member Derek Tittensor. Statistical modelling experts Christoffer Albertsen and William Aeberhard (HQP of JMF and Chris Field) were also present along with Stephanie Smedbol (representing Tim Stone and Dale Webber both of VEMCO). The participation of Jon Pye and Lenore Bajona is evidence of our efforts to coordinate and integrate with the OTN Data Centre. In fact, Jon Pye later helped us organize the ICFT workshop discussed below.

The 'Modelling of Animal Movement' Workshop that was held at the 3rd ICFT was extremely popular with over 30 participants (and a waitlist of 6) including those from Canada, Australia, Belgium, France, Ireland, Nigeria, South Africa and the United States. Representatives from OTN Industry Partners, Kintama and VEMCO were also present as were representatives from the Nova Scotia government and the OTN ISAC. HQP of Don Bowen and Chris Taggart attended as well as Brian Jones from OTN Data Management.

The OTN Statistical Modelling Group on GitLab has been successful at coordinating HQP with OTN collaborator Ian Jonsen.

Project 4.8 is a ‘cross-cutting activity’ born out of the OTN Canada Phase II Proposal. The mandate of Project 4.8 is to ensure that existing and future OTN technologies (and infrastructure) are properly

integrated into the network (as well as globally) so as to maximize their impact. These technologies and infrastructure include observing technologies and tools for statistical modelling and visualization. As such, Project 4.8 is focused on methodological developments (and transfer of knowledge) essential to a variety of projects/collaborators across all of OTN. Project 4.7 is centered on scientific questions that can be answered by using Grey seals as Bioprobes. The link between these two projects is that the complexities inherent to the Grey seal data are driving visualization and modelling methodologies forward. Stuart Carson's PhD thesis, for example, is devoted to developing new spatio-temporal models for data collected by bioprobes (those these need not be Grey Seals). In essence, datasets resulting from Project 4.7 comprise but one of a number of case studies being utilized in Project 4.8. To this end members of both projects meet together regularl

e) Scientific and/or engineering significance

In order to answer scientific questions of relevance to OTN, we must have both effective visualization tools and sensible models. Only then can we gain the scientific knowledge critical to understanding both the continental shelf and open ocean ecosystems. Our group is developing novel techniques using cutting edge software so that complex models can be fitted to data in a fraction of the time that has typically been required. These models are both accurate and robust to deviations in the underlying process and/or the measurement. With the computational gains that have been achieved we are now beginning to understand the spatial ecology of marine animals and predicting how their distribution will be affected by anthropogenic factors (e.g. climate change, fishing). What's more, we are quickly disseminating our new knowledge to the network via the workshops and the Gitlab account.

We remain very confident that our platform of choice (R/TMB) can efficently fit all of the statistical models we require and also interface well with rgl to produce desired data visualizations. In the next few months we will introduce a version of our state-space models that can also handle discrete behaviours. This will be a huge addition to our toolbox and is highly anticipated by the animal movement modelling community. Having spatial expert Elias Krainski from the Department of Mathematical Sciences at the Norwegian University of Science and Technology visit proved extremely fruitful for advancing the spatio-temporal modelling analyses that SC and JMF have been pushing forward in collaboration with Don Bowen.

f) Significance of research to the community/public

The ocean is a challenging environment to work in due to our inablity to observe it directly. There are indeed many challenges associated with marine data. The research that is being undertaken here is allowing real ecological questions to be answered that were simply out of reach before. For example, our ICFT workshop was designed to introduce TMB and demonstrate its utility for quickly analyzing complex animal movement data. Participants were able to build their analytical skills in a hands-on environment with help from experienced TMB-users. After a concise introduction to TMB, and a work-through of a simple spatial analysis of VPS data for answering a particular ecological question of interest, participants were simply encouraged to take advantage of this opportunity to learn about TMB in a stress-free environment.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

All of the workshops that we have offered to date have been at capacity with participants from both within and outside of OTN as well as from both within and outside of Dalhousie U. This speaks to the intra-network collaborations this group both generates and supports.

In July KW, Eduardo Martins, and MAM began a collaborative review project on the available statistical methods for presence-absence data in the aquatic realm collected by radio, pit tag, and acoustic telemetry. This project group has now grown to include JMF, Lee Gutowsky, and Vivian Chu. KW is also working with Don Bowen and JMF to determine the differences in foraging tactics of two distinct grey seal populations (Sable Island and Hay Island, Nova Scotia). KW has collaborated with Glenn Crossin to help tag Atlantic salmon smolts and adults in the Bras d'Or lakes of Cape Breton, Nova Scotia, and she has provided feedback on analyzing the results of this telemetry project. Finally, she has worked with Aaron Fisk and Eddie Halfyard to begin visualizing the data from a VPS system monitoring the movements of yellow perch and largemouth bass in an experimental pond in Southern Ontario.

In collaboration with Chris Taggart's lab, SC is attempting to determine how the spatial correlation in species biomass relates to the correlation in biodiversity.

MAM is the co-chair of ideasOTN, a committee within OTN that was created to support and develop new ideas for syntheses and ensure that these get carried through by involving members from across the network. ideasOTN has 6 synthesis projects in progress and at least 8 projects in preparation. These projects involves a variety of OTN members including MSc students (e.g. KW, Émilie Simard), PhD students (e.g., Nathan Furrey, Vivian Nguyen), post-docs/research associates (e.g., Eduardo Martins, Damian Lidgard), and PIs (e.g. Steve Cooke, Julian Dodson) from diverse universities (e.g., Dalhousie, Carleton, Windsor, Waterloo, British Columbia). During the 3rd ICFT MAM participated in the Futures Panel meeting, the Governance dinner, and the Futures Committee meeting. MAM is currently involved in a variety of collaborations within the network. Most of these projects involve a wide set of collaborators including JMF and Glenn Crossin with whom she is working on how to use TMB to increase the efficiency of state-space models, David Yurkowski with whom she is working on state-space models for continuous behaviours that can also incorportate dive information, Melanie Beguer-Pon and Emillie Simard with whom she is working on a review of movement studies in cetaceans and also Steve Kessel, Nigel Hussey, Steve Cooke, Aaron Fisk, Michelle Heupel (OTN Australia) with whom she is working on a project looking at how the distribution of field studies may affect our understanding of animal movement. In addition she is working with Damian Lidgard on a perspective piece showing how terrestrial studies can inform marine space-use concepts and with Nigel Hussey and Robert Harcourt on an opinion piece on how to protect the habitat of Arctic species.

In addition to the research projects and supervisory roles mentioned above, JMF continues to serve on both the ISAC for the OTN as well its IDMC.

b) Interaction/Outreach to Broader Community

In February MAM offered a graduate module in the Department of Biology at Dalhousie U on how to visualize and handle spatial data in R.

On May 28 JMF and KW visited Springvale Elementary School to talk about the importance of the oceans. Some of the technology currently used by OTN was demonstrated to the students including a VR100 mobile receiver and V8 tag.

9. Dissemination of information and results

a) Refereed journal articles (3 total) – accepted/published

Albertsen C.M., K. Whoriskey, D.J. Yurkowski, A. Nielsen & J. Mills-Flemming. Fast-fitting of robust state-space models to animal movement data via Template Model Builder. Ecology (In Press).

Cosandey-Godin, A., Krainski, E., Worm, B. & Mills Flemming, J. (2015) Applying Bayesian spatio-temporal models to fisheries bycatch in the Canadian Arctic. Canadian Journal of Fisheries and Aquatic Sciences, 72: 1–12 (2015) dx.doi.org/10.1139/cjfas-2014-0159.

Lennox, R., K. Whoriskey, G. Crossin, and S. J. Cooke (2015) Influence of angler hook-set behaviour relative to hook type on capture success and incidences of deep hooking and injury in a teleost fish. Fisheries Research 164:201-205.

b) Refereed journal articles (3 total) – submitted

Marie Auger-Méthé, C. Field, C.M. Albertsen, A.E. Derocher, M.A. Lewis, I.D. Jonsen, J.E. Mills Flemming. State-space models' dirty little secrets: even simple linear Gaussian models can have estimation problems. Submitted to Proceedings of the Royal Society B, preprint available on arXiv: 1508.04325

R.J. Lennox, I. Mayer, T. B. Havn, M. R. Johansen, K. Whoriskey, S. J. Cooke, E. B. Thorstad, and I. Uglem. Testing air exposure thresholds for European grayling Thymallus thymallus in a catch-and-release setting. Submitted to Boreal Environmental Research.

Stuart Carson, N. Shackell, J. Mills Flemming. Density Dependent Habitat Selection of Atlantic Cod and remnant sub-populations as revealed by a Spatio-Temporal Model. Submitted to Ecological Applications.

c) Conference presentations (4 total) – invited

Auger-Méthé, M., Jun 2015 Statistical Society of Canada Annual Meeting – Special session: Using TMB to Quickly and Robustly Solve Problems from Marine Ecology, Halifax, Nova Scotia.

Auger-Méthé, M., Dec 2014 Canadian Mathematical Society Winter Meeting – Special session: Dynamics of Biological Systems, Hamilton, Ontario.

Whoriskey, K., Jun 2015. Fast Fitting of Non-Gaussian State-Space Models to Animal Movement Data via Template Model Builder. 43rd Annual Meetings of the Statistical Society of Canada, Halifax, Nova Scotia.

Mills Flemming, J., May 2015. The Ocean Tracking Network: From Data to Knowledge. UBC Peter Wall Institute Research Roundtable, Vancouver, British Columbia.

d) Conference presentations (4 total) – contributed

Carson, S., Jul 2015. 3rd ICFT, Density Dependent Habitat Selection of Atlantic Cod on the Scotian Shelf as Revealed by a Spatio-Temporal Model, Halifax, Nova Scotia.

Whoriskey, K., Jul 2015. Template Model Builder (TMB) for Fitting Switching State-Space Models to Animal Tracks. 3rd ICFT, Halifax, Nova Scotia.

Mills Flemming, J., Jun 2015. Statistical Methods for Assessing Impacts of Overfishing, 43rd Annual Statistical Society of Canada Meetings, Halifax, Nova Scotia.

Carson, S., Jun 2015. Density Dependent Habitat Selection of Atlantic Cod on the Scotian Shelf, 43rd Annual Statistical Society of Canada Meetings, Halifax, Nova Scotia.

10. Other contributions and deliverables

c) Invited or contributed presentation/contribution at a workshop

Mills Flemming J., Apr 2015. Discussant at Workshop on Complex Spatio-Temporal Data Structures: Methods and Applications, Fields Institute, University of Toronto, Ontario.

k) Reference or training tools/materials (e.g handbook or guide)

MAM made available online the materials from her graduate module titled 'GIS in R' , including a set of tutorials

l) Internet publishing, portal, blog, electronic publications

JMF has a NEWS page on her website (www.joannamillsflemming.com) that sporadically highlights OTN events of current interest.

n) Leveraging your research/funds in order to make a new contribution to another initiative

JMF continues to lead a CANSSI CRT project for which OTN is a partner organization. MAM together with David Campbell (Simon Fraser University) and Len Thomas (University of Saint Andrews) submitted a proposal for its 2017 scientific program. If successful interested researchers from both our group and the CANSSI CRT project team would meet for a week in Banff to address pressing issues concerning state-space models.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.9

2. Project Title: Salmonids in the north – species transition zones and beyond, predicting impacts of climate change

3. Project Leaders: Ian Fleming (Memorial U), Michael Power (U Waterloo), Ross Tallman (DFO-Arctic, U Manitoba), Aaron Fisk (U Windsor)

Other OTN Canada participants: S. Vagle, S. Hinch, S. Cooke, G. Crossin

Collaborators: Ian Bradbury (DFO-Atlantic, Memorial U), Brian Dempson (DFO-Arctic, U Waterloo), Anders Finstad (Norwegian Institute for Nature Research), Corey Morris (DFO-Atlantic), Martha Robertson (DFO-Atlantic), Marie-Julie Roux (Falkland Island Fisheries Department, UK)

4. Public summary of report

This past year we continued project fieldwork aiming to quantify marine behaviour and potential responses of salmonid fishes to climate change in areas of species transition along the Newfoundland-Labrador coast. Two PhD students were involved in the fieldwork completed at two study sites in 2015: Campbellton River (49.2 N) and Muddy Bay Brook (53.6 N). Supplementary sampling was completed at two other sites in conjunction with collaborations with Fisheries and Oceans Canada: Parkers Brook (Pistolet Bay, 51.5 N) to Gilbert Bay (52.4 N). The Cambridge Bay region project, focusing on searun Arctic char in the northern part of its range was continued for a third year with an additional 113 individuals tagged in the Wellington Bay region of Vicotria Island (69.4 N). In addition to continuing the data collection on char movement in the marine environment, we have now deployed additional receivers in the freshwater with the aim to identify critical spawning habitats. A manuscript on Arctic char marine migrations based on the first two years of data is now under review in a leading journal in the field. Three new projects, that involved three new MSc students at the University of Manitoba, are focused on the movement, ecology and traditional knowledge of Arctic Charr in the communities of Kitimeot (principle community is Cambridge Bay), the Kivalliq (western Hudson Bay, principle community Rankin Inlet) and the Qikiqtaaluk (Cumberland Sound – Principle community, Pangnirtung). Combined Project 4.9 has projects that span all the major regions where there are Arctic Charr.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Ingeborg Mulder	PhD	100	100	1 Sept 2014	31 Aug 2018
Research Topic: Nearshore marime habitat use by Arctic charr: competetive interactions with other salmonids					
Kristin Bøe	PhD	100	100	1 May 2014	30 Apr 2018
Research Topic: Life history of repeat spawning salmon and their temporal and spatial use of marine habitat and interactions with other salmonids					
Jean-Sébastien Moore	PDF	100	0	1 Jan 2013	1 Sept 2016
Research Topic: Marine migrations of anadromous Arctic char in the Cambridge Bay region					

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Sarah Arnold	MSc	100	100	1 Jan 2015	31 Dec 2016
Research Topic: Traditional knowledge, fishery independent data and tracking to understand the arctic charr of the Kivalliq region					
Gabrielle Grenier	MSc	25	25	1 May 2015	31 Dec 2016
Research Topic: Arctic charr movements in the Cumberland Sound region					
Kevin Crook	MSc	25	15	1 May 2015	31 Dec 2016
Research Topic: Arctic charr movements in the Qikiqtaaluk region					

b) Role, activities, and opportunities for training

Project Component 1 - Salmonids in the species transition zone: Component 1 provided opportunities for two PhD students, Ingeborg Mulder (start date 1/09/2014, end date 31/08/2018) and Kristin Bøe (start date 1/05/2014, end date 30/04/2018). These two students are co-supervised by Power and Fleming, and are responsible for playing a leading role in the intellectual refinement of the project component and completion of all associated technical analysis of Arctic charr, Atlantic salmon and brook trout data, respectively. They are being trained in telemetry data collection and analytical methods central to the collection, collation and dissemination of OTN-related data and supplementary supporting methods, including lipid analyses, stable isotope analyses and otoltih thermometry. Training emphasis is further being placed on the integration of telemetry-related methods with other technical/analytical methods fundamental to ecological research. To that end every effort has been made to select collaborative project partners that can supplement typical university-based learning with experiential learning (e.g., DFO) and inter-network exchange opportunities (e.g., via ArcticNet) will be pursued to ensure broadly trained HQP are produced. In all instances, HQP will be exposed to, and mentored within, an environment that integrates fundamental research with real-world issues (e.g., climate change).

Project component 2 - Arctic char in the high Arctic: Jean-Sébastien Moore (PDF) planned and participated in the 2015 field season and spent over a month in the Arctic. He collected the data from an array of 42 acoustic receivers and performed maintenance on all units. He submitted a manuscript (now in review at Canadian Journal of Fisheries and Aquatic Sciences) on the data collected by the same array between 2013-2014. He also presented these results at the international Arctic Change conference in Ottawa in 2014. He will present updated results at the upcoming ArcticNet Annual Scientific Meeting in Vancouver in December 2015, and is currently working on analyzing data for two more publications coming out of this work. MSc students Kevin Crook, Gabrielle Grenier and Sarah Arnold began there MSc projects on Arctic charr. All three students travelled to their respective field sites to begin and organize fieldwork.

6. Progress towards objectives/milestones

a) Overall objectives

Project Component 1 - Salmonids in the species transition zone

There has been no modification of the component 1 objectives, with the overall aim of the first project component being to quantify the migratory behaviour, and spatial and temporal patterns of estuarine and marine habitat use of co-existing salmonid populations as affected by niche segregation and life history in a changing climate. This is being studied in Atlantic salmon and Arctic charr, and secondarily brook

trout, from targeted populations in a region of species transition (Newfoundland/Labrador). Quantifying these patterns is important for addressing: [1] the degree to which species' phenologies and life histories facilitate temporal and [2] spatial (e.g., vertically, thermal environments) co-occurrence in estuarine and/or marine habitats, [3] species' sympatric versus allopatric distributions to provide evidence of niche compression and/or displacement, and [4] how species' migratory behaviour (e.g. depth and temperature use) and life history patterns vary along a latitudinal gradient and how these might be related to physical-biogeochemical oceanographic patterns. The data provided are also critical for answering [5] ecological questions regarding the consequent impacts of predicted climate change across much of the north (e.g., latitudinally-driven environmental [temperature] changes in species' distributions through effects on fitness [growth and reproduction] and competitive abilities).

Project Component 2 - Arctic char in the high Arctic

There has been no modification of the component 2 objectives, with the overall aim of the second project component being to quantify the migratory behaviour, and spatial and temporal patterns of estuarine and marine habitat use of anadromous Arctic char in the Cambridge Bay region. More specifically, the project addresses [1] the timing of transitions between salt- and freshwater and potential biological (length, weight, sex) and environmental (date of ice breakup, average temperature, tides) factors influencing this timing, [2] environmental drivers of habitat use in terms of general habitat categories (e.g., estuarine vs marine) and in terms of depth and temperature preference, and [3] temporal and spatial aspects of the mixing of different stocks recognized by fisheries management. An additional objective added recently following demands from the community of Cambridge Bay has been the addition of an acoustic array in the freshwater to identify critical spawning habitat.

Arctic Charr migrate between reproductive, feeding and over-wintering habitats. Migrations are critical to the success of Arctic Charr and are highly relevant to fisheries which are frequently prosecuted as interception fisheries along the migratory route. As well, Arctic Charr have multiple ecotypes that differ greatly in their migratory pattern. In particular, within most systems there are "resident" Charr and "anadromous" Charr. The resident form remains in fresh water throughout their lifetime and is thought to undergo relatively short migrations whereas the anadromous form migrates to and from the Sea each year for the purposes of feeding. The anadromous form becomes orders of magnitude larger than the resident form and is the basis for most of the fisheries managed by the Department of Fisheries and Oceans. The two forms are intimately linked and not genetically distinct. For Arctic Charr it is critical to fisheries management to understand both the pattern and seasonal timing of movements in the marine and freshwater environment and the likely drivers of change in these patterns. Our knowledge of movement patterns and the drivers for these is only conceptual at best and we are not in a position to make assessments of the effects of impacts of development and changing fishing patterns without better information. The Arctic Charr OTN program is designed to increase our knowledge of movement patterns in both the freshwater and marine phases of the life cycle and key factors that may influence movements and the expression of the anadromous and freshwater life histories. We require detailed information on the movements, climate effects on the ecosystem and early life growth patterns.

While Arctic Charr are throughout Nunavut and every community harvests Arctic Charr there are three focal areas for the Department of Fisheries and Oceans – river systems and nearshore ocean centered around Cambridge Bay, Pangnirtung and Rankin Inlet.

Movement Patterns

At Cambridge Bay we have focussed our efforts on the marine migrations and there has been an extensive grid of receivers developed in the marine environment. In the Cumberland Sound/Pangnirtung and the Kivalliq (Rankin Inlet) we have focussed on freshwater movement patterns. Unfortunately, the marine work in south Baffin Island was disrupted by the community in Pangnirtung expressing their legal right to deny permission for receivers in the marine environment. The project in Cambridge Bay is operated collaboratively between a post-doctoral fellow, Dr. Jean-Sebastien Moore and a DFO research biologist, Les Harris. Graduate students (of Tallman) at the University of Manitoba are the project executors in South Baffin (Angela Young) and the Kivalliq (Sarah Arnold).

Drivers of migration

Resident and anadromous Charr may be produced from the same brood and it is hypothesized that the growth patterns in early life history may determine the resulting proportions of anadromous versus resident Arctic Charr. A project to examine this aspect is with a University of Manitoba graduate student (Gabrielle Grenier) supervised by Dr. Tallman. Both abiotic (ice cover and temperature) and biotic drivers of the marine migrations may be in flux due to climate warming in the Arctic. The project at Cambridge Bay is measuring the abiotic marine factors. In the eastern Arctic a major change in many food webs is the expansion of the range of Atlantic Capelin. Two University of Manitoba graduate students (Kendra Ulrich, thesis completed 2014) and Kevin Crook (Thesis completed 2015) have done projects to determine if Arctic Charr will switch diet to capelin (confirmed by Ulrich) and if Capelin may be fully established (as in breeding populations) (Crook) in the eastern Arctic represented by Cumberland Sound.

b) Progress

The field work consisted of two main activities: the first part consisted of capturing and tagging fish migrating to the marine environment and the second consisted of tagging upstream migrants for purposes of monitor overwintering behaviour and potential species interactions.

Fish capture and tagging

Field work commenced in June, with initial plans to capture and tag out migrating fish at a DFO operated counting fence shifted to the capture and tagging of fish in the marine environment owing to high water levels that prevented initial installation and operation of the fence. Gill-netting and tagging in the marine environment results in 1 kelt and 69 Arctic charr being tagged. Lack of kelt capture resulted in redeployment of kelt tags to brook charr and with-holding of 65 Lotek geo-location (data storage) tags (DST) for use on Atlantic salmon in Campbellton River summer 2016. Nineteen brook charr were successfully tagged. Summaries of planned and accomplished tagging is given below in Tables 1 and 2.

Table 1. Overview of planned number and types of tags allocated to salmon and char and their life stages in the marine behaviour study.

Species	Life stage	Tag Type	Tag model	# of tags	~Battery life	#fish 2 tags	Total tagged
Atlantic salmon	Smolt	Acoustic	V9, no sensors	30	190 days	0	30
Atlantic salmon	Kelt	Acoustic	V9, temp	20	120 days	20	
Atlantic salmon	Kelt	Acoustic	v13, temp	20	667 days	20	

Atlantic salmon	Kelt	Logging	Lat2810 DST	65	365 days	40	65
Arctic charr	Juvenile	Acoustic	V9, no sensors	10	190 days	0	10
Arctic charr	Adult	Acoustic	V9, temp	20	120 days	0	
Arctic charr	Adult	Acoustic	V13, temp	20	667 days	0	
Arctic charr	Adult	Logging	Lat2810 DST	65	365 days	0	115
							Total= 210

Table 2. Overview of realized numbers and types of tags fitted to Arctic charr, Atlantic salmon and brook trout and their life stages in the marine environment.

Species	Life stage	Tag Type	Tag model	# of tags	~Battery life	#fish 2 tags	Total tagged
Atlantic salmon	Smolt	Acoustic	V9, no sensors	30	190 days	0	30
Atlantic salmon	Kelt	Acoustic	V9, temp	1	120 days	1	
Atlantic salmon	Kelt	Acoustic	V13, temp	0	667 days	0	
Atlantic salmon	Kelt	Logging	Lat2810 DST	1	365 days	1	1
Brook trout	Adult	Acoustic	V9, temp	18*	120 days	0	
Brook trout	Adult	Acoustic	V13, temp	1*	667 days	0	19
Arctic charr	Juvenile	Acoustic	V9, no sensors	10	190 days	0	10
Arctic charr	Adult	Acoustic	V9, temp	20	120 days	0	
Arctic charr	Adult	Acoustic	V13, temp	20	667 days	0	
Arctic charr	Adult	Logging	Lat2810 DST	16	365 days	0	56
							Total = 116

** Tags were originally planned for salmon kelts but allocated to brook trout after June 28*

For tracking purposes a total of 31 receivers were deployed in a manner to ensure that: [1] all the river/saltwater transitions zones in sandwich Bay/Muddy Bay Brook were covered and [2] fish would be detected when/if leaving the Sandwich Bay area. Receivers were deployed with the help of local help and Fisheries and Oceans Canada. Receiver retrieval began August 15th to ensure all receivers were removed by the end of the field season. Of the 31 receivers deployed all but one were retrieved, although local hires continue to search for the receiver. For purposes of linking movement to feeding ecology stable isotope samples were obtained , including baseline samples from the marine environment and tissue samples from 40 sea run Arctic char ranging from 21 to 50.5 cm. An additional 12 sea run brook

trout ranging from 25 to 32 cm were sampled for stable isotopes. The NunatuKavut Community Council and local community agreed to help obtain additional fish samples from the recreational and food fishery. Isotope samples are currently being processed at the University of Waterloo.

Tagging and Upstream Migration

Eighteen arctic char were recaptured at the salmon counting fence in the period June 12 to August 11. Of these, six were tagged with archival geo-location tags and 12 with acoustic transmitters. Another 34 charr tagged in the marine environment had successfully reached the over-wintering lake (Muddy Bay Pond), having successfully passed through the counting fence undetected. Four Arctic charr detected at the counting fence had entered the over-wintering lake prior to down-loading of the lake receivers just prior to departure (August 31). All recaptured char with acoustic transmitters were length measured and a second caudal fin clip was taken. The incision was inspected and the level of healing was assessed. Charr that were recaptured containing a DST tag were lethally sampled, and the DST tag was downloaded and re-implanted in a new charr.

To study over-wintering, 30 Arctic charr ranging from 36 to 48.5 (42.6 ± 3.8) cm and 30 Atlantic salmon ranging from 48 to 73 cm (56 cm ±0.051) was double tagged with Vemco acoustic temperature and accelerometer tags (Table 3). A small piece of caudal fin tissue was carefully removed from each tagged fish to link movement and temperature data with stable isotope data. To ensure that the accelerometer tags would have enough battery life to record and transmit data throughout winter, the tags were programmed to remain dormant for the first 90 days after activation. The temperature tags were programmed to transmit at 10 min intervals immediately after activation to ensure detections from the date of release. In addition, 19 brook trout ranging from 35 to 47 cm (40 cm ± 0.03) caught in or near the trap was fitted with the V13 temperature tags that was originally planned for Atlantic salmon kelts. The migration history of these fish was unknown when tagged, but the dark coloration may suggest that they were freshwater resident, and fin tissue clippings will be used to validate life-history type via stable isotopes.

After all the acoustic tags allocated to the overwintering study had been fitted to Arctic charr and Atlantic salmon, 49 archival geolocation (DST) left over from the marine study were fitted to Arctic charr.

Table 3. Summary of numbers and types of tags fitted to Arctic charr, Atlantic salmon and brook trout in the freshwater environmen.

Species	Life stage	Tag Type	Tag model	# of tags	~Battery life	#fish 2 tags	Total tagged
Atlantic salmon	Adult	Acoustic	V9, temp	30	519 days	30	
Atlantic salmon	Adult	Acoustic	V9, activity	30	219 days	30	30
Brook trout	Adult	Acoustic	V13, temp	19*	667 days	0	19
Arctic charr	Adult	Acoustic	V9, temp	30	519 days	30	
Arctic charr	Adult	Acoustic	V9, activity	30	219 days	30	

Arctic charr	Adult	Logging	Lat2810 DST	49	365 days	0	79

Total = 128

A total of 10 receivers were positioned in Muddy Bay Pond to track movement and temperature data of overwintering brook trout, char and salmon. The three first receivers were deployed on July 12th and were positioned close to where the pond empties into Muddy Bay Brook. The area closest to the river mouth was too shallow (~3 meter) to prevent receivers from freezing in during winter so the receiver here was deployed with a surface float and retrieved on August 23rd. Two more receivers were positioned in the pond on July 12th and the remaining 5 receivers were deployed on August 23rd. Temperature loggers were attached to three of the 10 receivers in the pond at two meter intervals up to 3 meters below the surface. The receivers were deployed at depths from 9 to 22 m. At intervals of ~500 m we did transects across the pond perpendicular to the shore and measured depth at every ~100 m. The measures ranged from 1.4 to 23.9 meters, and will be used to construct a rough bathymetry map.

Sixteen brook trout ranging from 35 to 47 cm was intercepted at or near the counting fence and lethally sampled. In addition, 2 fish that were tagged at the fence was recaptured and returned by recreational anglers. The marine migration history of the fish lethally sampled is unknown but will be determined by looking at the stable sulfur signature of the caudal fin clip. The coloration and parasite load of the sampled trout may, however, suggest that the majority were freshwater resident.

Observations of floy tagged salmon and char were frequently reported by anglers at the falls above the salmon counting fence, but no salmon or char were reported captured by anglers. In contrast, 4 brook trout tagged at the counting fence were recaptured. The first reported recaptured brook trout occurred at the falls above the fence two days after the date of the surgery. The head of the fish as well as the acoustic tag and floy tag was returned. The other three recaptures occurred in the pond, 37, 23 and 38 days after tagging. Two of these fish were returned together with tags whereas the head of the latter was returned with the tags. All returned tags and fish heads or whole fish were rewarded with $ 25 and the tags were fitted to new fish except one which turned out to be malfunctioning when tested with the manual receiver.

Of the upstream migrating char tagged at the fence between July 13 and 14, 25 individuals were detected in the pond by the receiver that was deployed there in the period July 12 to August 23. No detections of the salmon tagged at the fence was recorded in the pond during the same period. Of the brook trout tagged at the fence, 12 individuals were detected entering the pond of which three was recaptured by anglers.

Preliminary results and observations

Smolt detections

A total of 30 smolt were tagged and released at the salmon counting fence between June 22 and June 23. Of these, 25 individuals were detected leaving the river between June 24th and June 28th, on average 108 hours after the time of release (Figure 12). Two smolt tags were detected within Sandwhich Bay during mid-July (Tag ID 36440 and 36426). It is possible that these individuals were ingested by predators. Excluding these two tags, smolts were on average detected for 6 days (SD 2.12) before they

were observed leaving the bay. Of the 25 smolts detected in the estuary, 22 were detected leaving the bay south of Huntington Island (outer coast) whereas one smolt left the bay east of Huntington Island.

Kelt detection

The one kelt was gill-netted and tagged from the river mouth on June 13th. It was then detected for three days before the last detection occurred south of Huntington Island (outer Coast) on June 16th.

Arctic charr

Marine environment: The number of Arctic charr tagged in the marine environment can roughly be divided into two groups: i) Fish that were tagged early and performed extensive movements throughout the bay, ii) fish that were tagged later (early July) and were almost ready to move upstream again, these fish provided little telemetry data in the bay except direct movements to the river mouth. Looking at data from the first group. Charr movements surprisingly remained very local: mostly around Earl Island, at the river mouth or just south of the river mouth (Charlies Cove, Southeast Point). Only a few detections were found near other river mouths (Paradise River or Eagle River), and only one charr was observed leaving the bay. None to very few detections were found on receivers near the outer headlands. Looking at movement data of Arctic charr tagged this summer, it seems plausible that Sandwich Bay has its own local population of Arctic charr, originating from Muddy Bay Brook.

Brook trout

Marine environment: All except one brook trout were tagged in an area ~5 km southwest of the river mouth. Detections showed that these fish stayed primarily in close proximity to the area they were released except two fish that were last detected in the Paradise River entrance at the end of July, approximately 13 km from the release site. Seven individuals were never detected leaving the area of which they were released, whereas the remaining individuals where either last detected entering the MBB river mouth, or near the release location after being detected in the MBB estuary. No brook trout were detected after August 16th.

Ongoing activities at Campbellton River

There were no tagging activities in Campbellton River this year, however, two more tagged fish were recaptured in the river. One was intercepted at the smolt fence during the spring downstream migration and another salmon captured during the upstream migration at the adult counting fence. Both fish had expulsed the Lotek geolocation tags so that no data could be retrieved. Efforts to retrieve receivers deployed in Notre Dame Bay are still ongoing, and as of December 11th, 28 of the initial 31 receivers had been retrieved whereas one receiver was found in a fisherman's net in August 2015, close to the area it was deployed. The Notre Dame Bay data set was complemented with data from receivers in a DFO operated array located on the North East coast of Newfoundland which were downloaded during the summer 2015. This array has receivers ranging from 20 to 200 km from the Notre Dame Bay array and had detections from 22 salmon kelt tagged in Campbellton in 2014. These data are used in combination with geolocations from retrieved geolocation tags to estimate most probable migration routes. For all fish that were tagged in 2014 (n=54), a stable isotope analysis was performed, and for tagged fish recaptured the ensuing summer (n=8), a preliminary lipid and stable isotope analysis was performed. The aim is to make inferences about diet of reconditioning kelts to gain further insight into how spawning/life history influences the marine behaviour of anadromous salmonids.

Subsequent to the completion of the year 6 Science report the following activities related to the dissemination of project data have been completed:

Bøe, K., Fleming, I., Robertson, M., Power, M., Morris, C., and Dempson, B. 2015. Spatial extent and temperature use during the marine migration of consecutive repeat spawning Atlantic salmon (salmo salar). 69th Canadian Conference for Fisheries Research, January 7-9, 2015, St. John's, NF.

Mulder, I.M., Power, M., Fleming, I., Robertson, M., Morris, C., Dempson, B. and Green, J. M. 2015. Overwintering behaviour of anadromous Arctic charr (salvelinus alpinus) in two northern lake systems. 69th Canadian Conference for Fisheries Research, January 7-9, 2015, St. John's, NF.

Furthermore, and as listed below, the following publications are envisaged as a result of research work currently on-going.

Planned Scientific Papers

Mulder et al. A review of the life history of anadromous Arctic charr, Salvelinus alpinus, in North America. Environmental Biology of Fishes, November 2016.

Bøe et al. Environmental correlates to iteroparity in Atlantic salmon. Canadian Journal of Fisheries and Aquatic Sciences. December 2016

Mulder et al. Dispersal and temperature use of anadromous Arctic charr, Salvelinus alpinus, while overwintering in two northern lake systems. Journal of Fish Biology. March 2017.

Bøe et al. Combining archival and acoustic telemetry to infer migratory routes of consecutive repeat spawning Atlantic salmon. Marine Ecology Progress Series. March 2017.

Bøe et al. Atlantic salmon behavioral responses to climatic variation; the effect of sea surface temperature on diving behavior. Fisheries Oceanography. September 2017.

Mulder et al. Factors influencing carbon and nitrogen signatures in anadromous Arctic charr, Salvelinus alpinus, while foraging in the marine environment. Environmental Biology of Fishes, October 2017.

Bøe et al. Coupling stable isotope signatures and fatty acid composition to infer dietary changes related to spawning history in Atlantic salmon. Ecology of freshwater fish. December 2017.

Mulder et al. The use of acoustic accelerometer transmitters to determine movement activity of anadromous Arctic charr while overwintering in Muddy Bay Brook. Animal Biotelemetry. January 2018.

Bøe et al. Testing the assumption of winter 'dormancy' in Atlantic salmon kelts, a study of overwintering behaviour using accelerometer telemetry. Ecology of freshwater fish. March 2018.

Bøe is also two collaborative projects/manuscripts with Marie Auger-Méthé (use of state-space modelling approach to track animal movements combining acoustic and geolocation tag information) and Xavier Bordeleau (review/meta-analysis of Atlantic salmon kelt survival and contribution to population processes).

Planned Conference Presentations:

Bøe et al., CCFFR winter 2017. Coupling stable isotope signatures and fatty acid composition to infer dietary changes related to spawning history in Atlantic salmon. Ottawa, Canada.

Mulder et al., CCFFR winter 2017. Dispersal and temperature use of anadromous Arctic charr, Salvelinus alpinus, while overwintering in two northern lake systems. Ottawa, Canada.

Mulder et al. OTN symposium, summer 2016. Factors influencing carbon and nitrogen signatures in anadromous Arctic charr, Salvelinus alpinus, while foraging in the marine environment.

Bøe et al. OTN symposium, summer 2016. Testing the assumption of winter "dormancy" in Atlantic salmon kelts, a study of overwintering behaviour using accelerometer telemetry.

Auger-Méthé, M., Albertsen, C.M., Yurkowski, D.J., Bøe, K., Fleming, I.A. and J. Mills Flemming. 2016. Diving effects on surface movement: a state-space model approach. International Statistical Ecology Conference, Seattle, USA.

Bøe et al. Canadian Society for Ecology and Evolution. 2016. Environmental correlates to iteroparity in Atlantic salmon. St. John's, Canada.

Project component 2 - Arctic char in the high Arctic

This year was the third year of successful Arctic char fieldwork in the Cambridge Bay region, where an acoustic array of 42 receivers had been deployed in 2013. Units were retrieved and redeployed in 2015, and the data was downloaded and maintenance was performed on the units. An additional 13 receiver units were deployed in 2015 in the freshwater, bringing the toal number of receivers deployed in the area to 55. An addditional 113 individual charr were tagged in 2015, bringing the total number of tracked individuals to 233. All of these tags are Vemco V16 tags, including 30 sensor tags that measure temperature and depth (pressure). The data downloaded this year is currently being analyzed by PDF Moore. In addition, CTD casts were conducted along systematic transects in the area in each year to link charr migrations with physical variables. This work already resulted in a conference presentation at an international meeting and a manuscript, which is currently in review at the Canadian Journal of Fisheries and Aquatic Sciences. Another presentation will be given at a national conference in December and two more manuscripts are currently being prepared.

The expected output from the various graduate students of project compoenent 2:

Dr. Jean-Sebastien Moore - paper in Can J. Fish and Aquat Sciences (2016)

Les Harris – Stock assessment advisory report incorporating OTN findings into determination of sustainable harvest and fisheries management plan for Cambridge Bay 2016 or early 2017

Gabrielle Grenier – paper presented at International Charr Symposium (2015) and ArcticNet (2015), Undergraduate thesis – University of Manitoba (2015) – presently in first year of M.Sc.

Kevin Crook – Thesis on capelin completed 2016– possible follow on publications in 2017

Angela Young – M.Sc. thesis University of Manitoba (2017)

Kendra Ulrich – M.Sc. University of Manitoba 2014 – 2 journal submissions on changing Arctic Charr diet and diet relative to life history form

Sarah Arnold – Commenced M.Sc. September 2015 –

A lot of these projects have money from the Nunavut Implementation Fund ($30,000) , Nunavut Wildlife Management Board ($80,000) , Government of Nunavut ($100,000 with roughly $40,000 supporting OTN related work) and Nunavut Offshore Allocation Holders ($30,000).

c) Significant deviations

Project Component 1 - Salmonids in the species transition zone

There were no significant deviations from the proposed research plan for 2015 subsequent to the 2014 decision not to pursue field operations in Ungava Bay owing to the significant logistical challenges of setting telemetry arrays in a cold coastal marine environment with among the highest tides in the world and the lack of technical receiver deployment support that could be provided by OTN. Re-focussed efforts in Labrador (Muddy Bay Brook) as described in the 2014 report were carried out more or less successfully as planned, with receiver deployment support covered by provision of boats and personnel by DFO partners. Minor deviations to tagging plans occurred as outlined below owing to issues with high water, counting fence deployment and ease of river-related access. As a result tags were redeployed within the study from Atlantic salmon to Arctic and brook charr and withheld for 2016 field use on Atlantic salmon at the Campbellton study site.

Project component 2 - Arctic char in the high Arctic

There were no significant deviations from the proposed research plan for 2015. All goals were attained in the 2015 field season as in previous years. The only change in objectives was the addition of the receiving stations in the fresh water to document critical spanwing habitats.

d) Coordination and integration

Project Component 1 - Salmonids in the species transition zone

The co-PIs for this component, Michael Power and Ian Fleming, who are co-supervising the two PhD students, Ingeborg Mulder (University of Waterloo) and Kristin Bøe (Memorial University of Newfoundland), are in regular communication. The two students work closely together and were simultaneously deployed during the field work season to provide each other with operational assistance in the field. While one focuses on Atlantic salmon (K. Bøe) and the other on Arctic charr (I. Mulder), co-deployment allowed them to adjust and compare sampling procedures to permit the gathering of complementary data sets that will improve the comparisons of species tactics as per study objectives. Co-ordinated field work has also permitted identification of study synergisms that will enhance study publication record, i.e. inclusion of comparative marine feeding-fate study of resident salmonids. There is also regular communication with our DFO collaborators, particularly Corey Morris, Martha Robertson and Brian Dempson, who are critical to this study and sit on the supervisory committees on one or both of the PhD students. Thus we co-shared housing with DFO personnel supervised by M. Roberston and were supported logistically in the field by Corey Morris at the Gilbert and Pistolet Bay study sites.

Power attended a series of project meetings in St. John's in January 2015 attended by all collaborators and participated in the proposal defence of K. Bøe. Regular conference calls were used to co-ordinate field planning and students regularly collaborate via Skype. PhD student Mulder spent May in Fleming's lab preparing for field work and November in Fleming's lab collating field data with PhD student Bøe, with Bøe scheduled to spend February in the Power lab learning stable isotope techniques.

Project component 2 - Arctic char in the high Arctic

The co-PIs Aaron Fisk and Ross Tallman are in regular communication over this project component. Most of the coordination, however, is achieved by PDF Jean-Sébastien Moore and DFO biologist Les Harris, who works for R. Tallman. They communicate almost weekly to plan the field work, and both spent 5 weeks in the Arctic together working on all compoenents of the field season together. In addition, PDF Steve Kessel, who works on a different OTN project in the Arctic arena came to the field in Cambridge Bay for one week to help with the additional deployments in the freshwater. He also provided guidance for statistical analysis of previous results and is listed as an author on the submitted publication. Finally, the project team (JS Moore and L Harris) provided logistical support and help to the team of Steve Cooke (U Carleton), including PhD student Jaqueline Chapman, who came to Cambridge Bay to do a study on survivorship of Arctic char to catch-and-release angling.

e) Scientific and/or engineering significance

Project Component 1 - Salmonids in the species transition zone

The study as planned is the first to examine differences among key northern salmonids along the latitudinal gradient of co-occurrence. While such studies in Europe with brown trout, Atlantic salmon and Arctic charr have been completed, comparable studies have not been completed in Canada. In addition to telemetry data, the studies here are among the first to actively link movement with feeding ecology via the use of stable isotope analyses.

Project Component 2 - Arctic char in the high Arctic

The study is, as far as we know, the longest running acoustic telemetry study to target searun Arctic char. The long-term tracking data collected from several individuals will shed an unpredecently precise light on year-to-year variation in migratory behaviour of this long-lived fish. It is also significant by the fact that it takes place at high latitudes (>69 N) in an area of the Arctic Ocean that is ice-covered for most of the year.

f) Significance of research to the community/public

Project Component 1 - Salmonids in the species transition zone

Data provided by the study will be instrumental in helping communities along the Labrador coast better understand and contribute to the management of key salmonid species relied on to supplement incomes or provide subsistence resources. Data will also be key to helping partners, such as DFO, actively manage salmonid resources. As an example of high community interest, both PhD students were interviewed on local CBC Labrador Morning radio show (June 29) regarding their research.

Project component 2 - Arctic char in the high Arctic

The community of Cambridge Bay, close to where this project occurs, relies heavily on the local Arctic char for subsitence purposes. In addition, the largest commercial fishery for Arctic char operates in the region. The data generated by this research is directly communicated to Fisheries and Oceans staff, thus contributing the the sustainable management of this important fishery. In addition, all results are communicated to the local Hunters and Trappers Organization, responsible for the management of the subsistence fishery, by way of annual reports, posters, and in person presentations. The results thus empower them to make informed management decisions. Finally, several members of the community have, over the years, participated in the research project as hired staff. They have gained experience in fisheries science techniques, thus contributing to building capacity.

7. Difficulties encountered

☒ Scientific problems/difficulties

Project Component 1 - Salmonids in the species transition zone

The lack of the salmon counting fence during the char and salmon out-migration prevented us from catching and tagging the wanted number of char and Atlantic salmon kelts. This also caused us to spend considerably more time on fish capture than anticipated. In addition to gill-netting, efforts were made to angle for kelts both near the river mouth and in known pools further upstream. This entailed some difficulties due to the lack of road access, as all the gear necessary for fish holding and surgery had to be brought to site on foot and could not be stored on sites due to disturbance from bears. A hole in the fence was discovered in July and it became evident that the fence was not checked on a regular basis before this date. This is a probable explanation for the high number of tagged Arctic charr that was not recaptured at the fence but detected in the pond.

Project component 2 - Arctic char in the high Arctic

Our main difficulties over the last two years have been in last-minute changes to our schedule because of uncertain ice-conditions, thus preventing the sailing on the R/V Martin Bergmann, the research vessel used for the majority of our equipment recoveries. This year was also the first time that we lost moorings. Two moorings were lost on the west coast of Wellington Bay near to shore. We suspect that thicker than usual ice dragged the moorings away from their deployment location. We will attempt to change our strategy in the future years to make our moorings shorter, but it should be noted that the very shallow depths of Wellington Bay makes this challenging.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Project Component 1 - Salmonids in the species transition zone

As noted above, there has been active exchange between labs for the PhD students and several partner meetings. A large field planning meeting occurred in January in St. John's (Power, Fleming, DFO), subsequent field planning teleconferences occurred in March and April. DFO partners and the project co-shared accommodation in the field, with DFO providing logistical support for receiver deployment, fish capture and access to other technical field support. PhD students have met regularly with DFO collaborators in St. John's. DFO has further provided supplementary access to historical sampling data

in Labrador and at Campbellton River useful for adding scientific perspective to data currently being collected. Finally, DFO scientists sit as active committee members on PhD committees of both students.

Project component 2 - Arctic char in the high Arctic

As noted above, the co-PIs Tallman and Fisk are in communications regularly regarding this project, but most of the communication and coordination is done by PDF Moore and DFO biologist Harris, who are in weekly phone contact. They also spend several weeks in the field together each year. Finally, as mentioned earlier two HQP from other OTN projects and labs also collaborated with project component 2. PDF Kessel came to Cambridge Bay to help with deployment and collaborated on the writing of the manuscript under review mentionned earlier. PhD Chapman from the Cooke lab received logistical support and advice from the members of the research team. Finally, PDF Moore met Ingeborg Mulder in Ottawa during the 2014 Arctic Change meeting to discuss their respective projects.

b) Interaction/Outreach to Broader Community

Project Component 1 - Salmonids in the species transition zone

Outreach has been conducted in Labrador via involvement with the Gilbert Bay regional Fisheries and Ecosystem Workshop (April 2105) held in Port Simpson, Labrador. The aim of the meeting was to update local stakeholders on the nature and aims of current fisheries research being conducted along the Labrador coast, with attendance at the workshop facilitated as a result of collaborative linkages with DFO. Both students delivered talks to the workshop. The workshop put students in contact with the NunatuKavut Community Council (NCC), responsible for co-ordinating local interests in the management and use of fishery resources. The PhD students also a held public meeting at the end of their fieldwork on 25 August in Cartwright, where they presented the work they did over the summer and some preliminary results.

Project Component 2 - Arctic char in the high Arctic

Regular communication between PDF Moore and DFO biologist Harris and the Cambridge Bay Hunters and Trappers Organization ensures that leaders in the community are informed of the details of the research plan, and learn of the results in details. Posters are updated yearly and placed in prominent areas of the town, and community presentations are also given yearly.

9. Dissemination of information and results

b) Refereed journal articles (1 total) – submitted

Moore, J.-S., L.N. Harris, L. Bernatchez, R.F. Tallman, A.T. Fisk (In review) Acoustic telemetry reveals stock mixing and preference for near-shore and estuarine habitats in anadromous Arctic Char (Salvelinus alpinus) from the Canadian high Arctic. Canadian Journal of Fisheries and Aquatic Sciences

d) Conference presentations (1 total) – contributed

Moore, J.-S., Harris, L.N., Tallman, R., Bernatchez, L., Fisk, A. (2014) ArcticNet Annual Scientific Meeting, Ottawa, ON

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

Boe and Mulder, interview on the CBC Labrador Morning radio show (June 29) regarding PhD research activities at Muddy Bay Brook.

b) Invited or contributed open-to-public presentation/contribution

PhD students also a held public meeting at the end of their fieldwork on 25 August in Cartwright, where they presented the work they did over the summer and some preliminary results.

c) Invited or contributed presentation/contribution at a workshop

Boe, K. Interrelation between anadromy and iteroparity in shaping life history. Presentation on PHD research, Gilbert Bay Regional Fisheries and Ecosystem Workshop. April 2105. Port Simpson, Labrador.

Mulder, I. Movement patterns of Arctic charr in the nearshore marine environment and overwintering lakes. Presentation on PHD research, Gilbert Bay Regional Fisheries and Ecosystem Workshop. April 2105. Port Simpson, Labrador.

h) Data deposition to OTN Data Centre

Tagging data, receiver data and VUE files (downloaded from the receivers) in the process of being deposited to OTN Data Centre.

n) Leveraging your research/funds in order to make a new contribution to another initiative

We leveraged the OTN equipment in the Cambridge Bay deployment to obtain funding from the Marine Environmental Observation Prediction and Response (MEOPAR) Network grant for project "Observing and Responding to Pressures on Arctic Marine Ecosystem Services" Lead applicant: Dr. Brent Else, U of Calgary -- $312,000

11. Collaborations with industrial and government partners

a) Partners

Project Component 1 - Salmonids in the species transition zone

As described earlier, we work very closely with DFO (Northwest Atlantic Fisheries Centre) collaborators (Martha Robertson, Corey Morris and Brian Dempson) on this project. They are intimately involved in all aspects of the study, from project design to field work to data analysis to student supervision. The research carried out in the project relates directly to DFO's research and management of anadromous salmmonids in the Newfoundland and Labrador region. We also collaborate with Lotek Wireless on refining the use of DSTs for deployment on fishes, particularly salmonids.

Project Component 2 - Arctic char in the high Arctic

As described in several sections of the report, this project is done in close collaboration with DFO scientists, who have conributed at all levels of this research project.

b) Contributions

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	25000
2) Donation of equipment, software	10000
3) Donation of material	
4) Field work logistics	10000
5) Provision of services	
6) Other (specify): contribution of historical data	15000
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	5000
2) Salaries of managerial and administrative staff	5000
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	yes

Name of supporting organization: **University of Waterloo**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	10000
2) Salaries of managerial and administrative staff	
3) Other (specify): isotope sample analysis	7500
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	yes

Name of supporting organization: **Polar Continental Shelf Project (PCSP)**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): flight support in Cambridge Bay	19,000
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	yes

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.10

2. Project Title: Fish and marine mammal interactions in the high Arctic

3. Project Leaders: Aaron Fisk (U Windsor), Svein Vagle (DFO-Arctic, U Victoria), Steve Ferguson (DFO-Arctic, U Manitoba)

Other OTN Canada participants: D. Heath, K. Fennel, J. Sheng, J. Mills Flemming, D. Bowen, S. Iverson

Collaborators: Dale Webber (Vemco), Aaron McNeil (Australian Institute of Marine Science), Richard Crawford (East Carolina University), Robert Harcourt (MacQuarie University, Australia), Aqqalu Rosing-Asvid (Greenland Institute of Natural Resources), Rune Dietz (Aarhus Universitet, Denmark)

4. Public summary of report

This year marked the fourth and final field season of research in Resolute Bay, Nunavut. Good weather and ice conditions in many senses allowed this to be the most successful field season to date, with all intended goals accomplished as planned. All deployed equipment was successfully recovered and the data downloaded. Over the course of the entire project only one receiver mooring was lost, a staggering achievement given the difficult field conditions experienced in the high Arctic. In addition to the Resolute gear recovery, the Maxwell Bay receiver line (located around 150 km to the east), deployed in 2011, was recovered in its entirety aboard the fishing vessel Kiviuq, vessel time provided by the Arctic Fisheries Alliance. Given that this was the final year of the regional element of the study, no smaller fish species were acoustically tagged, but a host of biological samples were collected from several species, including sculpin and Arctic cod. Seven Greenland shark were captured by the longlining activities, six of which were sampled for blood and genetics, acoustically tagged and released. The seventh shark had been cannibalised on the line and was extensively biologically sampled. A thorough spread of CTD casts was conducted throughout the bay, to measure the spatial variability in oceanographic conditions. As vessels entered and exited the bay, sound measurements were taken at various locations throughout the bay. This will allow for soundscape models to be constructed and better inform us on the varying sound levels fish would have been subject to, in turn allowing us to assess its influence over the movements observed by the acoustic telemetry. Two meetings were held with the local community to discuss the progress and results of our research. The research team was also able to coordinate with the Qarmartalik School to conduct camera equipment and dissection training for several science classes. With the successful completion of the research project, the team were able to pack up all the accumulated research gear and ship it back south. The project overall has been a big success and the data collected will provide the bases for many more essetial publications for the region and field.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Steven Kessel	RA	100	100	1-Jan-2012	30-Jun-2016
Research Topic: Movements of fish species in the high Arctic; Project leader for Resolute Bay fieldwork					
David Yurkowski	PhD	100	0	1-Jan-2011	Aug-2015
Research Topic: Movements of ringed seals in the high Arctic					
Caitlin O'Neill	PhD	100	100	May-2013	Aug-2015
Research Topic: Oceanography of Lancaster Sound					
Justin Landry	MSc	100	100	1-Jul-2014	Aug-2016
Research Topic: Sculpin ecology					
Silviya Ivanova	MSc	100	100	1-Jul-2014	Aug-2016
Research Topic: Anthropogenic disturbances to sculpin behaviour and community relations between scientist and Inuit in the high Arctic					

b) Role, activities, and opportunities for training

Steven Kessel – project leader for Resolute Bay fieldwork. Steven was in charge of research schedules and activities, acoustic telemetry recoveries/maintenance/deployments, fish capture, tagging and biological sampling, vessel rentals, and coordination with the HTA and Qamartalik School. During this research year Steven was able to gain additional field experience on board a large commercial fishing vessel and continues firearms training. Steven also attended a data processing workshop at OTN this year. Finally, HQP Montana McLean came to Windsor to conduct a workshop on VPS data processing attended by Steven.

David Yurkowski – lead for seal tagging program. David did not perform any field work activities this year, but during this research year David participated in a data and visualization workshop through OTN at Dalhousie.

Caitlin O'Neill – lead for oceanographic research. Caitlin was in charge of all fieldwork activities related to oceanographic study. These included recoveries/maintenance/ deployments of oceanographic profiling equipment and conducting CTD cast throughout the bay. Caitlin also participated in additional research activities including, fish capture and tagging, acoustic telemetry retrieval and deployment and plankton tows. During this research year Caitlin gained vital small vessel experience and continued firearms training.

Justin Landry – MSc student focussing on sculpin ecology. Justin assisted Steven Kessel in all aspects of the acoustic telemetry and biological sampling study. In addition, Justin assisted with oceanographic profiling activities. During the research year, Justin gained vital small vessel experience and active firearms training. Justin gained extensive traning and experience dealing with stable isotope samples and the resultant data. Justin also attended the VPS data workshop hosted by Montana McLean.

Silviya Ivanova – MSc student focussing on anthropogenic disturbances to cod and sculpin behaviour and community relations between scientist and Inuit in the high Arctic. Silviya assisted Steven Kessel in all aspects of the acoustic telemetry and biological sampling study. In addition, Silviya assisted with

oceanographic profiling activities. She also conducted many hours of filming for her media project. Silviya organised and hosted the town meeting and communicated with several members of the local community, filming several interviews. During the research year, Silviya gained vital small vessel experience and active firearms training. Additionally she was trained in various aspects of acoustic telemetry research, including monitor mooring set up, deployment, recovery and maintenance, fish tagging, and data download and interpretation. Silviya also attended the VPS data workshop hosted by Montana McLean.

6. Progress towards objectives/milestones

a) Overall objectives

Provide a brief description of the overall objectives of this project.

a) To study environmental fish interactions in the context of a changing Arctic marine environment;

b) Identify the locations and depths and timings at which Arctic cod schools occur across a full year;

c) Define food webs in the high Arctic using stomach contents and stable isotopes;

d) Test acoustic tags and receiver arrays under Arctic conditions, with low temperatures, salinity stratified waters and ice;

e) Investigate ringed seal movements and diving behaviour throughout the Lancaster Sound area;

f) Determine how Greenland sharks interact with their environment in the Resolute Bay area, including whether they enter Resolute Bay and what large scale movements/migrations they undertake throughout the Canadian Arctic Archipelago (CAA);

g) Make oceanographic observations to; i) investigate the freshwater input into the study area; ii) define the temperature, salinity, and density characteristics of the water masses under consideration; iii) determine the tidal variability of the area and check this against available tidal models; iv) improve on our understanding of the bathymetry of the area; and v) to monitor the productivity of the study area. All these data will be used to develop and use suitable models to aid in the interpretation of the fish and marine mammal components of the study.

b) Progress

Describe progress towards meeting the project's objectives and specific milestones for the project.

Objective a) to date, 85 Arctic cod and 75 sculpin have been acoustically tagged. One full year of Arctic cod and three full year's sculpin data have been successfully downloaded. Data analysis is currently underway.

Objective b) data analysis from one full year of acoustic data and two years of hydroacoustic data have been obtained. Two papers relating to cod distribution have been publised (see below) and additional analyises for further publiactions is currently underway.

Objective c) tissues and stomach contents have been collected from >200 Arctic cod, >300 sculpin, several invertebrate species and plankton tows. Samples are currently being processed back at Windsor.

Objective d) two years of detection range test data has been obtain and analysed for the 69 KHz Vemco system. Data for five tag types has been processed and the shared with the development team at Vemco. A full year of 180 KHz range testing has been conducted for all available tag types and the data has been download, processing pending.

Objective e) satellite transmitters have been deployed on seven ringed seals. Environmental data (bathyemtry, ice concentration and chlorophyll-a data) has been obtained from several global climate datasets and analysis regarding seal behaviour relative to environmental conditions remain ongoing. Scientific papers detailing ringed seal behaviour and home ranges relative to environmental stochasticity and interference competition through space (high vs. low-latitudes) are underway and will be submitted for publication shortly.

Objective f) to date fourteen Greenland sharks have been acoustically tagged, and five satellite tagged, in the Resolute Bay area and a 18 have been sampled for genetics and stable isotopes.

Objective g) three years of oceanographic profiling data and four years of CDT casts have been obtained and is current being processed/analysed. Oceanographic data has been combined with acoustic tracking data to investigate the cues for Arctic cod presence and absence, which was included in the published manuscript.

All field work for the Resolute Bay study has now been collected. The field site has been successful closed down and all gear recovered and sent back from the field site. This includes the receiver line originally deployed off Maxwell Bay in 2011, facilitated by the Arctic Fisheries Alliance, organised and coordinated by HQP Nigel Hussey.

c) Significant deviations

This year was the most successful field work year for this study, in terms of no necessity to deviate from the research plan. The weather and ice conditions allowed for all research activities to be executed exactly as planned. Additionally 100% of the deployed gear was recovered, without a single loss. Over the entire corse of the study, only one receiver was lost.

d) Coordination and integration

All co-investigators (A. Fisk, S. Ferguson, S. Vagle), collaborators and HQP provided intellectual contributions to develop and establish the research plan for 2015. There were regular phone and email communication to discuss logistics, progress and problems with other co-investigators. There has been continuous communications with S. Vagle and D. Break on deployment and data acquisition by the CTDs, AMAR, and other oceanographic Benthic Pods. Extensive discussion with D. Webber and VEMCO staff over the design of acoustic monitor arrays, tag types and long-term range tests.

e) Scientific and/or engineering significance

The 180 KHz detection range test deployed in Resolute Bay represents the most comprehensive tests in terms of tag types, number of ranges, depths, length (1 full year), environmental conditions (open water

vs. ice cover) and location (74 N) ever under taken (D. Webber, Vemco pers. comm.). These data will inform on detection ranges and improve acoustic telemetry research in cold and deep waters.

Oceanographic data collected in Resolute Bay is among the most intensive ever collected in the Canada Arctic. These data will be instrumental in the development of oceanographic and climatic models as well as in the analysis and interpretation of the marine mammal and fish acoustic data.

Ocean-acoustic data collected in Resolute Bay is also among the most intensive ever collected in the Canada Arctic. This will allow us to build comprehensive soundscape models against which to assess fish behaviour dervided from the acoustic detection. This will provide and important tool for the assessment of the influence of anthropogenic noise in the Arctic marine ecosystem, a hot topic.

Acoustic tracking data of fish in Resolute Bay represents the only high resolution movement data of Arctic fish species in the Lancaster Sound region. The combination of the data with the extensive environmental data collected with provide vital insights to aid the prediction of future distribution in a changing Arctic.

f) Significance of research to the community/public

Climate change and increasing anthropogenic disturbances in the Arctic are highly important issues for the general public, but especially for the local Arctic communities. This research has and will provide essential insights into the effects of these environmental stressors and also provides baseline data from which to predict and assess future changes to this delicate and important marine ecosystem. The work of HQP Silviya Ivanova also seeks to directly engage to local community in the scientic research, in turn increasing local capacity building and willingness to directly use the results of this study.

7. Difficulties encountered

☒ No problems occurred during the reporting period

As mentioned previously, this years field season went seamlessly.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Numerous phone conferences were held between the Arctic OTN partners in the planning of the fieldwork season. Face to face meetings were also held within the Arctic OTN group and wider OTN community at the OTN Symposium at the ICFT meeting in Halifax. A number of phone conversation or meetings with OTN collaborators were carried out, these have led to new projects ideas and plans within the OTN umbrella but also with other funding agencies. HQPs Steven Kessel, Nigel Hussey and David Yurkowski attended the telemetry data modelling work shop in Halifax. Steven Kessel and Nigel Hussey have both been appointed to the new IdeasOTN committee. The group hosted HQP Montana McLean in Windsor, where she ran a workshop on the processing of VPS data. Finally, HQPs Nigel Hussey and Steven Kessel, and PI Aaron Fisk, were involved in the production of a telemetry review paper that was published this year in the journal 'Science'.

b) Interaction/Outreach to Broader Community

During the 2015 field season, a meeting was held with the Hunters and Trappers Association (HTA) in Resolute. During this meeting, the results of this study to date were presented and discussed with the HTA board members. A public meeting was hosted for the community of Resolute Bay. This was led by HQP Silviya Ivanova, presnting the results of the study to date and allowing the public to provide input for both the research and associated documentary film. HQPs Silviya Ivanova and Steven Kessel also hosted a science class in the lcoal resolute high school, teaching the students to use camera equipment and also disection techniques for local fish species. Several meetings/interviews were conducted by HQP Silviya Ivanova with members of the community to explore relationships between the community members and scientists working in the region. This will be used for content for a documentary being developed as part of her MSc. The field team also took several military and PCSP personnel out tagging Greenland shark, an experience main states as one of the best of their lives.

9. Dissemination of information and results

a) Refereed journal articles (6 total) – accepted/published

Crawford, R. (2015). Occurrence of a gelatinous predator (Cyanea capillata) may affect the distribution of Boreogadus saida, a key Arctic prey fish species. Polar Biology, 1-7.

Hussey, N. E., Cosandey-Godin, A., Walter, R. P., Hedges, K. J., VanGerwen-Toyne, M., Barkley, A. N., Kessel, S. T. & Fisk, A. T. (2014). Juvenile Greenland sharks Somniosus microcephalus (Bloch & Schneider, 1801) in the Canadian Arctic. Polar Biology 31, 493-304.

Kessel, S. T., Hussey, N. E., Crawford, R. E., Yurkowski, D. J., O'Neill, C. V. & Fisk, A. T. (2015). Distinct patterns of Arctic cod (Boreogadus saida) presence and absence in a shallow high Arctic embayment, revealed across open-water and ice-covered periods through acoustic telemetry. Polar Biology, 1-12.

Kessel, S.T., Hussey, N.E., Webber, D.M., Gruber, S.H., Young, J.M., Smale, M. and Fisk, A.T. (2015) Close proximity detection interference with acoustic telemetry: the importance of considering tag power output in low ambient noise environments. Animal Biotelemetry, 3, 5, 1-14. doi:10.1186/s40317-015-0023-1.

Yurkowski D.J., N.E. Hussey, C. Semeniuk, S.H. Ferguson & A.T. Fisk. Effects of chemical lipid-extraction and the utility of lipid-normalization models on stable isotope values in arctic marine mammal tissues. Polar Biology, 38:131-143.

Yurkowski D.J., S.H. Ferguson, C.A.D. Semeniuk, T.M. Brown, D.C.G. Muir & A.T. Fisk. Spatial and temporal variation of an ice-adapted predator's feeding ecology in a changing Arctic marine ecosystem. Oecologia (In Press).

b) Refereed journal articles (2 total) – submitted

Moore JS, Harris LN, Kessel ST, Bernatchez L, Tallman RF, Fisk AT (2015) Acoustic telemetry reveals stock mixing and preference for near-shore and estuarine habitat in anadromous Arctic char

(Salvelinus alpinus) from the Canadian high Arctic. Canadian Journal of Fisheries and Aquatic Sciences (In Review).

Yurkowski D.J., S.H. Ferguson, E.S Choy, L.L. Loseto, T.M. Brown, D.C.G. Muir, C.A.D. Semeniuk, & A.T. Fisk. Latitudinal variation in ecological opportunity and intra-specific competition indicates differences in niche variability and diet specialization of Arctic marine predators. Ecology and Evolution (In Review).

d) Conference presentations (12 total) – contributed

Kessel ST, Hussey NE, Cooke SJ, Heupel MR, Fisk AT (2015) Does the distribution of telemetry effort bias our understanding of global aquatic ecosystems? (Poster) International Conference of Fish Telemetry, Halifax, NS, Canada.

Hussey NE, Kessel ST, Aarestrup K, Cooke SJ, Cowley PD, Fisk AT, Harcourt RG, Holland KN, Iverson SJ, Kocik JF, Flemming JE, Whoriskey FG (2015) Aquatic animal telemetry: a panoramic window into the underwater world. International Conference of Fish Telemetry, Halifax, NS, Canada.

Pedro S, Fisk AT, Tomy G, Ferguson S, Muir D, Hussey NE, Kessel ST, McKinney M (2015) Mercury levels in invading subarctic forage fish versus arctic forage fish in the eastern Canadian Arctic. Society of Environmental Toxicology and Chemistry, Salt Lake City, UT, U.S.

Kessel ST, Hussey NE, Yurkowski DJ, O'Neill CV, Vagle S, Crawford RE, Ferguson S, Fisk AT (2015) Residency and distribution of Arctic cod (Boreogadus saida) in Resolute Bay, Lancaster Sound. Canadian Conference for Fisheries Research, Ottawa, ON, Canada.

Landry JJ, Ivanova S, Kessel ST, McLean M, O'Neill C, Nelson K, Fisk AT (2015) Using acoustic telemetry and stable isotopes to determine the trophic ecology of sculpin in the Canadian Arctic (Poster) International Conference of Fish Telemetry, Halifax, NS, Canada.

Landry JJ, Ivanova S, Kessel ST, McLean M, O'Neill C, Nelson K, Fisk AT (2015) Using Acoustic Telemetry and Stable Isotopes to Determine the Trophic Ecology of Sculpin in the Canadian Arctic. GLIER Colloquium, University of Windsor, Windsor, ON, Canada.

Ivanova S, Kessel ST, Landry J, McLean M, O'Neill C, Fisk AT, Nelson K (2015) Influence of human activity on common fish species in the high Arctic (Poster) International Conference of Fish Telemetry, Halifax, NS, Canada.

Ivanova S, Kessel ST, Landry J, McLean M, Fisk AT, Nelson K (2015) Human activity and fish movement in the High Arctic. GLIER Colloquium, University of Windsor, Windsor, ON, Canada.

Yurkowski D.J., S. H. Ferguson, A. Rosing-Asvid, R. Dietz, L. Harwood, T. Smith, T.M. Brown, C.A.D. Semeniuk, A.T. Fisk. (2015) Ringed seal foraging behaviour across the Arctic: a bio-indicator of fish distribution? International Conference of Fish Telemetry, Halifax, NS, Canada.

Yurkowski D.J., S.H. Ferguson, C.A.D. Semeniuk, A.T. Fisk (2015) Spatial variation in the ecology of an Arctic marine mammal in a warming climate. The Wildlife Society, Winnipeg, MB, Canada.

O'Neill, C. (2015) Marine Mammal Vocalisations in the High Arctic: Resolute Bay, Nunavut. Acoustics Week in Canada Conference, Halifax, NS, Canada.

O'Neill, C. and S. Vagle. (2015) Passive acoustic monitoring and ambient noise in the High Arctic: Resolute Bay, Nunavut. 170th Meeting of the Acoustical Society of America, Jacksonville, FL, USA.

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

Steven Kessel - Today Show (NBC) – How to survive or escape a shark attack;

Steven Kessel - Polar Research Feature (Canadian Geographic Magazine) – Feature Article;

b) Invited or contributed open-to-public presentation/contribution

Ivanova S, Hussey NE, Claussen JE, Kessel ST, Smit J, Fisk AT (2015) Environmental Protection & Stewardship – caring for and protecting what matters most in the Arctic. Resolute Bay, NU, Canada.

d) Invited or contributed presentation/contribution at a seminar series

Kessel ST (2015) From the Bermuda Triangle to the Arctic Circle: a journey of adaptable aquatic research techniques. Lake Ontario Fisheries Station, Ontario Ministry of Natural Resources, Picton, ON, Canada (Seminar Series).

Kessel ST (2015) From the Bermuda Triangle to the Arctic Circle: a journey of adaptable aquatic research techniques. Department of Biology, Florida Southern College, U.S. (Seminar Series).

e) Awards received

Caitlin O'Neill- Canadian Acoustical Association - Fessenden Student Prize in Underwater Acoustics

h) Data deposition to OTN Data Centre

Pending

l) Internet publishing, portal, blog, electronic publications

Caitlin O'Neill and Steven Kessel. Profiles from the Arctic. http://www.arcticprofiles.ca/

11. Collaborations with industrial and government partners

a) Partners

Collaborating with Lois Harwood (DFO- Yellowknife) and Tom Smith (EMC Eco-Marine Corporation - Quebec) on ringed seal tracking data from the western Arctic (i.e. Amundsen Gulf and Beaufort Sea).

Collaborating with JASCO Applied Sciences, using their automated acoustic marine mammal and vessel detection software. They also supplied us with an Autonomous Multichannel Acoustic Recorder (AMAR), which is currently deployed in Resolute Bay for a year.

b) Contributions

Name of supporting organization: **CFI**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Polar Continential Shelf Project**	**Year 6** (2015)
Cash contributions to direct costs of research	$23,052
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$23,052
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	yes

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.11

2. Project Title: Deep-water Arctic marine fishes: developing commercial fisheries and interactions with marine mammals

3. Project Leaders: Aaron Fisk (U Windsor), Kevin Hedges (DFO-Arctic, U Manitoba), Svein Vagle (DFO-Arctic, U Victoria), Steve Ferguson (DFO-Arctic, U Manitoba), Daniel Heath (U Windsor)

Other OTN Canada participants: I. Fleming, S. Hinch, S. Cooke, R. Tallman, K. Fennel, J. Sheng, J. Mills Flemming

Collaborators: Wayne Lynch (Government of Nunavut), Margaret Treble (DFO-Arctic), Dale Webber (Vemco), Fred Whoriskey (OTN), Aaron McNeil (Australian Institute of Marine Science)

4. Public summary of report

The projects centered on commercially important Greenland Halibut and bycatch species Greenland Shark and Arctic skate movements throughout the Baffin Island coastal region have been successful this past year. All the acoustic moorings located in Scott Inlet and Sam Ford Fjord were serviced and re-deployed in a similar array to that which was established in the previous year. The detections on these moorings provide insight into the inshore/offshore connectivity of Greenland Halibut populations that can be used for future management considerations when developing inshore artisanal Inuit fishing operations. As Greenland Sharks are a major by-catch in the Greenland Halibut fishery, and which very little is currently known about their biology and migration patterns, Scott Inlet has become an important area of study for this species given their high abundance in this area, the presence of juveniles, and the current acoustic data which suggests that multiple individuals return on a yearly basis. This year, more Greenland Halibut and Greenland Sharks were tagged in Scott Inlet to further this research into future years, including also adding aspects of capture related stress indicators and high-resolution accelerometers to measure the impact of fishing on by-catch. The Cumberland Sound moorings were also retrieved, serviced and re-deployed in similar locations to previous years, with four additional moorings added. A new acoustic array was established in Qikiqtarjuaq, another coastal Inuit community on Baffin Island with interests in developing a Greenland Halibut longline fishery. Multiple Greenland Halibut were acoustically tagged and released within the area (n = 60). Similar to Scott Inlet and Cumberland Sound, investigations in this area will focus on the predominant location of fish at different times of the year, and serve to potentially investigate the transient behaviour of Greenland Halibut throughout the deep-water fjords of Baffin Island and all three study sites (Scott Inlet, Cumberland Sound and Qikiqtarjuaq). Data on marine mammal presence in both Scott Inlet and Cumberland Sound was also collected through moorings equipped with SM3M/SM2M hydrophones, which were once again re-deployed in Scott Inlet, as well as oceanographic sensors to establish yearly environmental parameters within the system. The Arctic Charr genetic project has progressed well, with DNA extraction from tissue samples collected in 2014 completed and a panel of 14 microsatellite markers tested on Arctic Charr DNA. Genotyping is progressing well, and over 100 new samples were collected in the summer of 2015 - DNA is being extracted and archived for genotyping. Acoustic monitoring of marine mammals is an important tool to observe several species simultaneously and assess trophic relations. Here, we used passive acoustic monitoring (PAM) methods to monitor the occurrence of marine mammals over an annual cycle (2013) in Scott Inlet, Nunavut. We investigated the

environmental correlates of the presence of marine mammals and found that sea ice coverage strongly influenced our detections of marine mammal sounds. Narwhal and bowhead whales were only present before the area was covered in ice in the fall while the presence of bearded seals and walruses could only be detected after the ice was formed. The tidal phase, the time of the day, the water temperature at 300 m deep and the air temperature all influenced our detections of narwhal clicks. This PAM study has been submitted to a journal and provides a baseline measure for the presence of marine mammals over the seasons in Scott Inlet. We have continued with further longterm deployment of PAM in the same area (n = 4) as well as Cumberland Sound (n = 4) to document changes in the phenology of marine mammals in relation to taged fish and environmental changes.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Jeannette Bedard	PhD	100	100	Sept-2011	Dec-2015
Research Topic/current employment (if no longer OTNC HQP): Physical oceanography and acoustics					
Nigel Hussey	RA	75	0	1-Jan-2010	30-Jun-2016
Research Topic/current employment (if no longer OTNC HQP): Oversight/development of acoustic telemetry mooring placements, tagging of fish, analysis of data, co-supervision of MSc					
Amanda Barkley	MSc	75	100	1-May-2013	Aug-2015
Research Topic/current employment (if no longer OTNC HQP): Greenland shark/halibut tagging, sampling, & data analysis					
Natalie Reinhart	PhD	10	0	1-Jan-2014	31-Dec-2014
Research Topic/current employment (if no longer OTNC HQP): Killer whale predation in the eastern Canadian Arctic					
Chen Liu	MSc	100	100	1-Jan-2015	31-Dec-2017
Research Topic/current employment (if no longer OTNC HQP): genetic analysis of arctic char samples					

b) Role, activities, and opportunities for training

All HQP are involved in designing and providing input and ideas for the projects they are involved in. This also includes travelling to the arctic to use the equipment involved in the field work component of the project. HQPs also perform the data analysis that pertains to their field.

Jeanette Bedard (PhD): analysis of year-round oceanographic data (such as temperature, dissolved oxygen and salinity) collected by moorings.

Nigel Hussey (RA): Oversight and development of acoustic telemetry mooring placements, tagging of fish, analysis of data, co-supervision of MSc

Amanda Barkley (MSc): assisting in mooring servicing and re-deployment along with tagging and sampling Greenland Halibut and Greenland Shark. This also includes data analysis for Greenland Halibut tracking within Scott Inlet for the years 2012-2014 as well as capture stress for both Greenland Halibut and Greenland Sharks.

Natalie Reinhart (PhD): withdrew from program

Chen Liu (MSc): carrying out genetic analysis of arctic char samples

6. Progress towards objectives/milestones

a) Overall objectives

1) Test and apply new acoustic tracking technology to Arctic marine ecosystems that experiences low temperatures, salinity stratified waters and ice;

2) Monitor, quantify and describe oceanography of nearshore and deep water arctic marine ecosystems for use in understanding animal movements and for development of arctic and larger scale climatic and oceanographic models;

3) To quantify the residency and movement of Greenland halibut in Scott Inlet, an important commercial fish for developing Inuit fisheries in the region and examine residency/movement in relation to environmental variables, and the presence of large predators and marine mammals;

4) To quantify larger system-system movements of Greenland halibut tagged in Cumberland Sound, Qikiqtarjuaq and Scott Inlet

5) To determine the feeding ecology and trophic interactions of Greenland halibut through extensive sampling of multiple tissues and animal size classes for chemical tracer work tied with acoustic telemetry data

6) To study the trophic structure and species interactions in the deep water system of Scott Inlet through major sampling of trawl caught species (inverts to fish) and chemical tracer analysis which will be analyzed concurrent with acoustic telemetry data of Greenland halibut;

7) Undertake cross disciplinary/cross network research by examining the first ever measures of stress in deep water Arctic species - Greenland halibut, Greenland shark and Arctic skate;

8) Determine how Greenland sharks, apex predators and by-catch species, interact with their environment in Scott Inlet by examining movements, depth and temperature preferences and feeding ecology using acoustic tags and acoustic monitor arrays, pop-off satellite tags and chemical tracers.

9) Determine vertical and horizontal movements patterns of juvenile Greenland sharks in Scott Inlet using satellite and acoustic telemetry and chemical tracers;

10) Quantify post release survival and behviour of Greenland sharks and Greenland halibut using high resolution acclerometers and cameras (48 hour deployments).

11) Quantify species interactions of Greenland sharks and Greenland halibut using high resolution accekleormeters and cameras (up to 5 day deployments)

12) Quantify the feeding ecology, dive behaviour, distribution and movement of marine mammals (ringed seal, beluga, narwhal and bowhead whales) using passive acoustic listening devices (C-PODs and AURALs), boat based surveys, and chemical tracers in Scott Inlet.

13) Genotype Lake Arctic Charr life history types at 10-15 microsatellite loci to determine whether the migratory and resident forms are genetically separate - this assist in the management of the developing local fishery and in collaboration with telemetry projects

14) Quantify differences in gene transcription among the different life history types of Arctic Charr in at genes associated with saltwater tolerance and immune function.

b) Progress

1) The Scott Inlet acoustic array (80 – VR2W-69), oceanographic equipment (8 stations) and marine mammal listening devices (2 SM2M and 1 SM3M) were successfully retrieved this year and the data offloaded from the devices. This data will provide more evidence to support the seasonal use of Scott Inlet by Greenland Halibut as well as variations in behavioural patterns between resident and seasonal fish.

2) All acoustic receivers within Scott Inlet were redeployed, while switching certain monitoring stations with 10 VR4Ws. Ten temperature loggers were also deployed with two dissolved oxygen sensors, and two benthic pods. One shallow water (SM2M) marine mammal hydrophone was deployed with two deep-water (SM3M) hydrophones (two in Scott Inlet, the other at the entrace to Clyde River)

3) A total of 69 Greenland halibut, 15 Arctic skate and 8 Greenland sharks were internally tagged with various V16 and V13 acoustic tags this year in Scott Inlet, increasing the total number of tagged fish in this system to 240 Greenland halibut, 20 Arctic skate and 67 Greenland sharks.

4) Three Greenland sharks in Scott Inlet were tagged with pop up archival satellite tags for one-year deployment periods in Scott Inlet/Sam Ford Trough. These tags were attached to the dorsal fin of sharks using the attachment disc method developed by PDFs Hussey, Kessel and PI Fisk which proved very successful in the previous year. These sharks were also outfitted with mark-report tags.

5) Six deployments of high resolution acceleroemeters and cameras were atttached to Greenland sharks and successfully retrieved. These data will assess post release survival and species-interactions.

6) A total of 12 new moorings were deployed in Qikiqtarjuaq, and 60 Greenland Halibut tagged. This is a new study area added to the overall arctic network that will add greater knowledge to the connectivity of inshore deep-water channels in the Arctic. A benthic pod was also deployed in this area to collect oceanographic data.

7) A total of 15 moorings were deployed in Cumberland Sound, to continue work in this area to move the Greenland Halibut management line to the entrance of the Sound.

8) Samples were collected from all tagged fish (Greenland Shark, Arctic skate and Greenland Halibut) that will be used for both chemical tracer analysis as well as stress measurments to look at capture induced stress and survival in tagged fish. This work is in conjunction with PI Cooke to better understand survival and stress in these little known arctic species.

9) Tissue samples from Arctic Charr have been collected (for both microsatellite and gene expression studies) and DNA has been extracted. Microsatellite markers have been selected and are being tested on Arctic Charr DNA.

c) Significant deviations

Qikiqtarjuaq was added to the study system this year as a new project looking at seasonal migrations of Greenland Halibut in a second deep-water fjord system as well as to provide a better understanding of

the population connectivity between multiple coastal sites (ie Scott Inlet, Qikiqtarjuaq, and Cumberland Sound).

d) Coordination and integration

Regular conference call amoung PIs and HQP to plan and organize field work (particularly sample needs), report on data and discuss papers, were held (about once per month). We also held in person meetings at the ICFT in Halifax, which included members from Project 4.10. Data analysis for papers has also been integrative, for example PhD student Jeannette Bedard has analyzed and organized all the range test data for the soon to be submitted Ecological Application paper on Greenland Halibut movement in Cumberland Sound.

e) Scientific and/or engineering significance

This research provides some of the first insight into the movements and seasonal habitat use of Greenland Halibut, Arctic skate and Greenland Sharks. The Cumberland Sound system has provided evidence of movement between deep-water pockets in the south of the Sound to shallower water in the North when ice begins to develop, connecting two populations of fish that were once considered to be separate. The Scott Inlet system has determined that there is connectivity between the inshore and offshore populations of Greenland Halibut, as they enter the inshore environment in the summer, ice free months, and then leave again as the ice develops. Yet these seasonal movements are potentially limited to smaller fish, as future investigations in this area will focus on the residency of larger (primarily >50cm) Greenland Halibut. Qikiqtarjuaq was added to the system this year to further investigate the inshore/offshore connectivity of Greenland Halibut on the Baffin Island coast and with the offshore region where important commercial fisheries are established. The data for Greenland sharks in Scott Inlet show the first annual returns of this species to specific locations, i.e. several tagged animals return to the site each year. These data in conjunction with other moorings such as Maxwell Bay, where three sharks were detected, are demonstrating large scale movements and connectivity in the Arctic and providing the first inisghts in to lare scale and long term movements of this little known species. Satellite tag data on Greenland sharks is adding to a growing database that is currently revealing unique vertical movement behaviours and combined with novel satelite technology is allowing development of models to more accurately reconstruct horizontal movements of these deep water animals. High resolution acceleroemeters attached to Greenland sharks linked with the use of hook timers and stress measurements provide the first data on post release survival for this species which will directly inform commercial fisheries handling of this bycatch species. In addition, long term deployments of these loggers are examining the natural behaviour of this species and predator-prey interactions within Scott Inlet. Marine mammal moorings are providing the first data on seasonal occurrence patterns of several species at Cumberland Sound and Scott Inlet/Clyde River. These data are also showing timing of marine mammal species occurrence with Greenalnd shark and halibut detections provide an understanding of multi species movements and linkages.

f) Significance of research to the community/public

This research has major implications for the communities in the Canadian North. The Arctic is faced with poor socio-economic conditions that center around a lack of employment opportunities. This research is focused on studying the commercially important Greenland Halibut, with particular focus on movements through management boundaries that will contribute to the establishment of better and fair quotas. Studying seasonal abundance will also give insights into potential locations to establish Inuit

artisanal fisheries that can be profitable to the local communities. However, due to the fact that scientific knowledge on Greenland Halibut is limited and especially lacking for the major bycatch species, Arctic skate and the Greenland Shark, this research will not only help to develop fisheries, but to also do it in a sustainable manner.

7. Difficulties encountered

☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)
☒ Other (specify): Weather

Equipment and technology issues: The mooring that was not recovered in 2014 could not be successfully recovered this year, as the release continued to communicate, yet would not respond to the release command. A second release failed to even communicate with the transducer, and therefore was left without being serviced. We will discuss the technician issues with OTN technician Duncan Bates to see if there are other options for release or communications. We will discuss trawling to retrieve the recivers with the ship captain, however the moorings are deep (> 500 m) and trawling is an expensive and time consuming process in this system (in 2015 the trawler was not operational) and time is limited.

Other (weather): The ice conditions within Cumberland Sound caused a delay to work in the area. For this reason, no new fish could be captured and tagged given the short time-frame available to access the area. Two moorings were also inaccessable due to the heavy ice conditions and therefore will need to be serviced next year. We do not anticipate any issues with retrieving these receivers if ice conditions are normal (2015 was an extreme year for ice).

8. Networking and outreach

a) *Intra-network collaboration and partner meetings*

Numerous phone conferences were held between the Arctic OTN partners in the planning of the fieldwork season. Face to face meetings were also held within the Arctic OTN group and wider OTN community at the OTN Symposium at the ICFT meeting in Halifax. A number of phone conversation or meetings with OTN collaborators were carried out, these have led to new projects ideas and plans within the OTN umbrella but also with other funding agencies. HQPs Nigel Hussey attended the telemetry data modelling work shop in Halifax and was appointed to the new IdeasOTN committee. The group hosted HQP Montana McLean in Windsor, where she ran a workshop on the processing of VPS data. Finally, HQPs Nigel Hussey and PI Aaron Fisk were involved in the production of a telemetry review paper that was published this year in the journal 'Science'.

b) *Interaction/Outreach to Broader Community*

Throughout this research is has been a priority to keep the local Arctic communities involved with each project. This involves meetings with the Hunters and Trappers Association of Clyde River (Scott Inlet project), Qikiqtarjuaq, and Pangnirtung (Cumberland Sound) to explain each project. In accordance with requests from the Clyde River HTA, each year the scientific group has also provided a public presentation (either in a open community meeting or on the local radio station) that involves explaining the project and allowing an open question period for the public. There is typically always a member of the local community or of Inuit heritage present on the boat during the field season that will hopefully increase understanding and outreach to the local communities.

9. Dissemination of information and results

a) Refereed journal articles (4 total) – accepted/published

Hussey, N.E., Kessel, S.T., Aarestrup, K., Cooke, S., Cowley, P., Fisk, A., Harcourt, R., Holland, K., Iverson, S., Kocik, J., Mills Flemming J. and Whoriskey, F. (2015) Aquatic animal telemetry: a panoramic window into the underwater world. Science, 348, 1255642.

Bedard, J. M., Vagle, S.V., Klymak, J.M., Williams, W.J., Curry, B. and Lee, C.M. (2015) Outside influences on the water column of Cumberland Sound, Baffin Island. Journal of Geophysical Research: Oecans. Online first DOI: 10.1002/2015JC010811

Ferguson, S, Higdon, J, Tallman, R., Fisk, A. and Hussey, N.E. (2014) The ghost of competition past: body size, trophic ecology, diversity and distribution of global shark and pinniped species. Journal of Marine Animals and their Ecology, 7, 23-39.

Kessel, S.T. and Hussey, N.E. (2015) Tonic immobility as an anesthetic for elasmobranchs during surgical implantation procedures. Canadian Journal of Fisheries and Aquatic Sciences.

b) Refereed journal articles (2 total) – submitted

Barkley AN, Cooke SJ, Fisk AT, Hedges K, Hussey NE (In review) Capture-Induced Stress in Deep-Water Arctic Fish Species. Polar Biology.

Haward, M., Stephens, T., Jabour, J., Apostle, R., Gazit, T., Hindell, M., Hussey, N.E., Meeuwig, J.L., Saunders, P., Sykes, K., Techera, E., VanderZwaag, D.L. and Whoriskey, F.G. (In review) Ocean Tracking: New frontiers for managing marine species at risk. Frontiers in Ecology and Environment.

c) Conference presentations (2 total) – invited

Hussey, N.E. (2015) Trophic structure and complexity of marine food webs: insights and implications from stable isotope analysis of marine predators at individual, population and ecosystem scales. 5th Brazilian Congress of Marine Biology, Recife, Brazil.

Hussey, N.E. (2014) The ecological information derived from tissue samples: the power of chemical tracers in elasmobranch ecology. Sharks International, Durban, South Africa.

d) Conference presentations (6 total) – contributed

Barkley, A.N., Hussey, N.E., Hedges, K. and Fisk, A.T. (2015) Seasonal movements of the deepwater flatfish, Greenland halibut (Reinhardtius hippoglossoides), in the coastal fjords of Baffin Island. Canadian Conference for Fisheries Research, Ottawa, Canada.

Hussey, N.E., Godin, A.C., Walter, R.P., Hedges, K.J., VanGerwen-Toyne, M., Barkley A.N., Kessel, S.T. and Fisk, A.T. (2015). An Arctic Enigma: Where are all the juvenile Greenland sharks? Canadian Conference for Fisheries Research, Ottawa, Canada.

Pedro, S., Fisk, A.T., Tomy, G., Muir, D., Hussey, N.E., Kessel, S., McKinney, M. (2015) Mercury levels in invading subarctic forage fish versus arctic forage fish in the eastern Canadian Arctic. SETAC, Salt Lake City, USA.

Fisk, A.T., Kennedy, J., Young, A., McNair-Landry, S., Hyndman, W. and Hussey, N.E. (2014) Arctic charr discoveries and adventures on the sixth largest lake in Canada: Nettilling Lake, Nunavut. Arctic Change 2014, ArcticNet Conference, Ottawa, Canada.

Ferguson, S.H., Higdon, J.W., Tallman, R.F., Fisk, A.T. and Hussey, N.E. (2014) Shark predation: is this how seal distribution will change with warming? Arctic Change 2014, ArcticNet Conference, Ottawa, Canada.

Davis, B., Hussey, N.E., Campana, S. and Whoriskey, F., (2014) The use of an ecosystem top-predator monitoring system to acoustically track sharks of the Northwest Atlantic and Eastern Arctic Oceans. Sharks International, Durban, South Africa.

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

BBC Shark Series - Hussey provided advice and support to BBC film team on Greenland sharks over two month period, Barkley joined the production team in the field to sample sharks and participate in filming: http://www.bbc.co.uk/programmes/p02n7s0d

Canadian National Geographic - report on Greenland shark tagging work underway across the Caandian Arctic by Hussey et al.: http://www.canadiangeographic.ca/blog/posting.asp?ID=1616

CBC Halifax news report on release of Sceince review paper, "Aquatic animal telemetry: a panormaic window into the underwater world" by Hussey et al. (2015): http://www.cbc.ca/news/canada/nova-scotia/ocean-tracking-advances-turning-whales-and-seals-into-oceanographers-1.3111739

b) Invited or contributed open-to-public presentation/contribution

Hussey presented to the Canadian Teachers Association on the Arctic Ocean Tracking telemetry program.

Hussey gave public presentation for World Wildlife Fund event held during the International Fish Telemetry Conference in Halifax 2015 and assisted organization of public quiz including leading international shark experts.

c) Invited or contributed presentation/contribution at a workshop

Hussey, N.E. (2015) Telemetry tracking and management of sharks in Canadian waters. IMAS ACORN workshop, Hobart, Tasmania, Australia.

e) Awards received

Barkley- Ontario Graduate Scholarship (2014-2015), Northern Scientific Training Programe (2013-2014)

11. Collaborations with industrial and government partners

b) Contributions

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$318,000
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Government of Nunavut**	**Year 6** (2015)
Cash contributions to direct costs of research	$330,000
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.12, 4.13, 4.14, 4.15

2. Project Titles:

4.12 Pacific salmon commercial and First Nations fisheries: delayed mortality, behaviour and physiology of released bycatch in coastal waters

4.13 Tracking anadromous adult salmonids in Canada's three oceans to evaluate the sustainability of catch-and-release angling practices – behavioural and physiological perspectives on estuarine fisheries

4.14 Seasonal movements and spawning migrations of White Sturgeon

4.15 Survival and movement rates of out-migrating juvenile Pacific and Atlantic salmon

3. Project Leaders (4.12): Scott Hinch (UBC)

Other OTN Canada participants: S. Cooke, T. Farrell, K. Miller, D. Patterson, A. Fisk, I. Fleming, M. Stokesbury
Collaborators: Michael Davis (United States NOAA)

Project Leaders (4.13): S. Cooke (Carleton U)
Other OTN Canada participants: S. Hinch, T. Farrell, A. Fisk, R. Tallman, I. Fleming
Collaborators: Dave Patterson (DFO-Pacific), M. Robertson (DFO-Atlantic)

Project Leaders (4.14): G. Crossin (Dalhousie U)
Other OTN Canada participants: S. Cooke, S. Hinch, T. Farrell, M. Litvak, M. Stokesbury
Collaborators: Dave Patterson (DFO-Pacific), Kyle Hanson

Project Leaders (4.15): S. Hinch (UBC)
Other OTN Canada participants: S. Cooke, K. Miller, R. Thomson, I. Fleming, J. Mills Flemming
Collaborators: Dave Patterson (DFO-Pacific), Fred Whoriskey (OTN)

4. Public summary of report

The OTN Pacific Arena research is focused on Pacific salmon and white sturgeon given their ecological, cultural and socio-economic importance. All of the research involved using innovative high-tech telemetry tags that transmit information to receivers spread throughout the coast and rivers. Prior to the development of such technology it was impossible to study these fish across large spatial scales. Research has covered several life stages including outmigrating salmon smolts and upriver migrating adult salmon and sturgeon. For example, team members traveled to the Chilko watershed where they tagged sockeye salmon smolts and predatory bull trout in an effort to identify where and how mortality occurs during their journey to the ocean. Team members also worked in the ocean where they tagged adult salmon to understand the behaviour of different stocks on their way to spawning grounds. The

team utilized novel telemetry tags that measure tailbeats of salmon enabling the estimation of swimming speeds and energy use. Given the prevalence of fisheries along their homeward migration, we also studied the effects of capture and release on survival and behaviour of adult salmon, Arctic char, and sturgeon incorporating assessments of stress physiology and disease using physiological biopsy. Laboratory work on adult salmon and sturgeon in captivity complemented the field work and are helping to identify physiological mechanisms of stress and mortality including tagging burden. The work conducted involved extensive partnerships with Fisheries and Oceans Canada, First Nations groups, ENGOs, anglers, and commercial fishers. Collectively OTN research in the Pacific Arena has already informed fisheries management and conservation by providing information on the behaviour and survival of salmon and sturgeon.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Sources of other support	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Eduardo Martins	RA	10	0	Ero Liber	1 Sept 2009	Dec 2016
Research Topic: salmon life history and movement modelling						
Doug Braun	PDF	10	0	InStream Ltd	1 June 2011	Dec 2016
Research Topic: salmon movement biology						
Erika Eliason	RA	100	100		1 Jan 2011	Dec 2016
Research Topic: salmon physiology						
Wenming Zhang	PDF	5	0	UCalgary	1 Aug 2013	Dec 2014
Current employment (if no longer OTNC HQP): PDF UCalgary						
Katrina Cook	PhD	100	25	NSERC	1 Sept 2012	Dec 2016
Research Topic: capture/release physiology and behaviour						
Amy Teffer	PhD	50	0	NSERC	1 Sept 2011	Dec 2016
Research Topic: pathogens and disease in salmon						
Arthur Bass	PhD	50	0	NSERC/MITACS	1 Sept 2012	Dec 2016
Research Topic: capture/release and disease in salmon						
Matt Drenner	PhD	100	25	UBC	1 Sept 2009	Sept 2015
Current employment (if no longer OTNC HQP): PDF with Hinch at UBC						
Nolan Bett	PhD	50	0	NSERC/MITACS	1 Sept 2011	Sept 2016
Research Topic: homing physiology and behaviour in salmon						
Natalie Sopinka	PhD	20	0	NSERC/MITACS	1 Jan 2011	June 2015
Current employment (if no longer OTNC HQP): PDF UWindsor						
Nathan Furey	PhD	100	10	NSERC/MITACS	1 Sept 2011	Sept 2016
Research Topic: salmon smolt movement and survival ecology						
Vivian Nguyen	PhD	100	0	NSERC	1 Jan 2014	Dec 2016
Research Topic: human dimensions of salmon capture						
Montana McLean	PhD	100	50	NSERC	1 Jan 2014	Dec 2016
Research Topic: white sturgeon movement ecology						
Vanessa Minke-Martin	MSc	50	0	NSERC/MITACS	1 Sept 2013	Sept 2015
Research Topic: thermal ecology of migrating adult salmon						
Melissa Dick	MSc	100	40	NSERC	1 July 2014	Dec 2016
Research Topic: effects of handling on maturing salmon						

Name	Title	% Time in project	% Support from OTNC	Sources of other support	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Marianne Corriveau	MSc	20	20	UOttawa	1 Oct 2013	Sept 2014
Research Topic: human dimensions of salmon capture						
Stephen Healy	MSc	100	0	NSERC/MITACS	1 Sept 2014	Dec 2016
Research Topic: salmon smolt movement and survival ecology						
Lisiane Hahn	PDF	10	0	Neotropical consulting	1 Jan 2015	Dec 2015
Research Topic: biologging						
Mandy Banet	PDF	25	0	NSF	1 Sept 2012	July 2015
Current employment (if no longer OTNC HQP): Assistant Professor, California State Univ (Chico)						
Graham Raby	PhD	100	0	NSERC	1 Sept 2009	May 2015
Research Topic: effects of commercial fishing handling on bycatch survival						
Mike Donaldson	RA	15	15	CRC press	1 Sept 2015	Aug 2016
Research Topic: review of handling effects and salmon vitality						
Nicolas Burnett	Res. Asst.	50	0	NSERC/BChydro	1 Sept 2014	Sept 2015
Research Topic: effects of salmon swimming behaviour on passag success						
Jacqueline Chapman	PhD	100	20	NSERC	1 June 2014	Dec 2016
Research Topic: effects of handling/release on salmonids in the 3 oceanseff						
Collin Middleton	MSc	50	0	NSERC/MITACS	1 Sept 2013	1 May 2016
Research Topic: effects of physiology, temperature and water quality on migration success of adult salmon						
Mike Lawrence	PhD	20	0	NSERC	1 Sept 2014	Dec 2016
Research Topic: biologging physiology and cardiac function in salmonids						
Melanie Kuzyk	Res. Asst.	50	0	BCHydro	1 May 2015	1 Oct 2015
Research Topic: assistant						
Justin Fleming	Res. Asst.	50	50	ENGAGE	1 May 2015	1 Oct 2015
Research Topic: assistant						
Tonya Prystay	Res. Asst.	100	0	NSERC	1 July 2015	1 Oct 2015
Research Topic: biologger assistant						
Sofia Jain	Res. Asst.	100	0	NSERC	1 July 2015	1 Sept 2015
Research Topic: catch/release assistant						
MaryAnn Watson	MSc	100	0	ENGAGE	1 June 2015	1 Oct 2015
Robert Lennox	PhD	30	30	NSERC	1 Oct 2015	Dec 2016
Research Topic: Catch/release science / biologgers						
Dan Struthers	MSc	30	0	NSERC/OGS	1 Oct 2015	30 Sept 2016
Research Topic: Spatial ecology of fish						

b) Role, activities, and opportunities for training

Research on Pacific salmon and sturgeon requires significant interaction with stakeholders, use of specialized equipment, performing laboratory assays and analyses, and working in environments (e.g.,

on research vessels) that are inherently dangerous and require extensive training. As such, we have a team of technical staff (e.g. Andrew Lotto, Nich Burnett, Taylor Nettles, Matt Casselman - all based in BC) that are essential to project success and play an important role in training of HQP. Our technical staff includes highly competent individuals who deal with aspects of site reconnaissance, biosecurity, field equipment maintenance and operation, vessel/vehicle fleet maintenance and operation, field camp logistics, technical operations of data collection, and most importantly mentoring of students in the field and lab. In 2015 additional technical planning assistance was provided by Lisa Donaldson (Cooke's lab manager in Ottawa) for work in the Arctic. Our work requires extensive interaction with stakeholders (e.g. First Nations groups, fisher groups, ENGOs) which requires relationship building, consistency, and mutual respect – these activities are led by our technical staff. Moreover, technical staff plays critical roles in safety training and monitoring, ensuring that research activity is in compliance with university and government (provincial and federal) policies. Technical staff at the DFO Molecular Genetics Laboratory at the Pacific Biological Centre train HQP in molecular technologies and participate in the laboratory analyses as do technical staff at the DFO West Vancouver Laboratory Environmental Watch Program. Our technical staff serves a critical role as conduits of information from the public and other stakeholder groups to the investigators in our research program. Our technical staff are able to enhance their knowledge and further develop their abilities and skills through participating in workshops, local conferences, and meetings with partner and collaborator groups.

6. Progress towards objectives/milestones

a) Overall objectives

4.12 Pacific salmon commercial and First Nations fisheries: delayed mortality, behaviour and physiology of released bycatch in coastal waters

Our first objective is to provide information to fisheries managers and fishers on mortality of coastal migrating adult Pacific salmon associated with release after capture (hence forth termed 'delayed mortality') using different fishing gears and practices employed by the commercial and First Nations marine coastal fisheries sectors. Our second objective is to identify and test potential strategies for improving recovery of fish released from different fishing gears in order to recommend potential best practices for minimizing delayed mortality in coastal waters.

4.13 Tracking anadromous adult salmonids in Canada's three oceans to evaluate the sustainability of catch-and-release angling practices – behavioural and physiological perspectives on estuarine fisheries

Our objective is to characterize the fate of fish released from recreational fishing interactions relative to different handling and environmental characteristics. Anadromous salmonids will serve as a model and research activities will occur in estuarine areas (including lower rivers, river mouths, and nearshore coastal zone). In the Atlantic we will focus efforts on Atlantic salmon given their conservation status and sensitivity to fisheries interactions at warmer water temperatures. In the Pacific we will focus on coho salmon given their prominence in the recreational fishery and their conservation status (i.e. some stocks are endangered). In the Arctic we will focus on Arctic charr given that it is an emerging recreational fishery. No post-release mortality studies exist for coho salmon or Arctic charr, and the research that has been done on Atlantic salmon has all been focused on areas closer to spawning grounds. Estuarine environments have typically not been subject to intense fisheries but in the face of climate change, an adaptation strategy is to push recreational fisheries for anadromous species towards the ocean.

Underpinning this and other studies (especially 4.12) are efforts to understand the effects of our tagging procedures on fish so that we are able to isolate the effects of the fisheries stressors.

4.14 Seasonal movements and spawning migrations of white sturgeon

Our first objective is to provide basic information about the drivers of seasonal movements and reproductive patterns of white sturgeon in the Fraser River and its estuary, and of the short- to long-term effects of angling stress on survival. Our second objective is to provide information to fisheries managers and fishers on post-angling mortality patterns, and about basic life-history which can guide management and conservation actions. This will enable a set of potential best practices for minimizing angling related mortality, and identify areas and times of year when sturgeon are most susceptible to disturbance. Our third objective is to provide information on species interactions, specifically salmon-sturgeon, and sturgeon-sturgeon interactions.

4.15 Survival and movement rates of out-migrating juvenile salmon

The main objective is to characterize the migration rates and fate of juvenile sockeye as they migrate from natal freshwater areas into and through coastal areas, and to relate riverine, oceanographic, and climate features, and physiological/biological attributes of individuals, to behaviour and fate. The goal is to examine hypotheses about how environment and individual characteristics affect smolt survival, and to extend this to making predictions about the role of future climate scenarios.

b) Progress

4.12 Pacific salmon commercial and First Nations fisheries: delayed mortality, behaviour and physiology of released bycatch in coastal waters

To achieve the objectives we are using field studies with biopsy and acoustic telemetry and lab assessments to quantify mortality rates, sublethal consequences (behaviour, physiology, and injury) and recovery potential with different methods of fish capture, handling, and recovery. We examined adult coho, Chinook, chum and sockeye. Several papers were submitted/published in 2015 examining survival rates following beach seine, gillnet, trapbox, and purse seine capture; and, in some cases if assisted ventilation approaches (e.g. fish bags, fish boxes, or manual ram ventilation) influenced survival of released adult salmon and if RAMP (reflex action mortality predictors; a rapid assessment indicator of physiological impairment) is a useful approach for predicting post-release mortality. One of the primary results to date is that assisted ventilation has limited beneficial effects and may even be detrimental for aiding recovery and survival of released fish, except when a fish is extremely physiologically impaired. RAMP measures have proven to be highly predictive of delayed mortality in sockeye and coho salmon in riverine environments - we have just begun assessing this with chum salmon.

Using social science survey methods, and Knowledge Mobilization Theory approaches, in conjunction with the tagging and RAMP studies, DFO managers, ENGOs, and First Nations fishers were interviewed to gain an understanding of how they viewed telemetry and recovery research, how they feel it should/can be used to help them manage the fisheries resource and the threats and opportunities they face in regards to their fisheries. The primary findings were that DFO managers respect the work we are doing but the management structure of the fishery makes it difficult for them to utilize our scientific results (e.g. our delayed mortality estimates demonstrate how species, locale, fishing sector specific results can be). Specific guidelines and focussed direction is needed for them. We are now preparing a CSAS document to better assist managers. We also found that the majority of First Nations

fishers trusted the results of telemetry science and felt positively about how it could help fisheries management.

In summer/fall 2015, we conducted three field studies involving tagging and releasing > 800 adult sockeye that were captured by either First Nations gill net, beach seine or trap box at different locales ranging from the ocean/estuary to areas close to spawning grounds. We used capture time, amount of air exposure, RAMP and physiological factors (eg pathogen loads) as predictors of release and delayed mortality. Results are pending.

In summer/fall 2015, laboratory experiments were conducted at the DFO Cultus Lake Laboratory examining the effects of tagging types, temperature and maturation on adult sockeye physiological recovery and survival. Results are pending.

We continued with our assessments of new tag technology, specifically VEMCO accelerometer transmitters, and linkages between this technology and novel environmental monitoring approaches. Over 45 accelerometer transmitters were implanted into Seton River adult sockeye prior to their migration through turbulent flows to assess how acceleration, swimming speeds and activity affected migration success in relation to the encountered dynamic flow fields which were assessed in real-time using Acoustic Doppler Current Profiling (ADCP). Flow fields were experimentally altered by changing levels of flow out of certain siphon spillways at an upstream dam. Results indicate that burst swimming (and high levels of anaerobiosis) is required to pass through these areas of turbulent flow; however fish that burst swam the most were least likely to reach natal areas after passing the turbulent zone - particularly for females, indicating strong latent effects of anaerobiosis. ADCP results suggest that the turbulent zone is highly variable in water velocity and that some flows were 'super critical' supporting the accelerometer results that sockeye must swim anaerobically to pass. It also identified large reverse flow fields downstream of the turbulent zone which contributed to migration delay. It is worth noting that this research component involves collaboration with hydraulic engineers from U Alberta and represents a connection between OTN Canada and NSERC HydroNet Strategic Network. Papers on this work were written up and published in 2015.

Given that tagging of animals is central to the OTN Canada program, there is clearly a need for both a synthesis of existing data as well as the generation of new data to ensure that the welfare status of tagged fish is maintained and that data from tagged fish are representative of untagged conspecifics. We continue to assess 'handling effects' through our research dealing with facilitated recovery and RAMP and to develop 'best practices' in terms of sizes of transmitters that can be used in field telemetry studies, particularly on juvenile salmon. Specifically, we completed several relevant handling effects and review studies and published them this past year in the primary literature and in technical reports. We also continued with a collaborative field project with DFO, integrating our work into a stock assessment study on Harrison River sockeye, in order to directly examine how tagging attachment type (external vs internal) influenced survival of migrating adult salmon. This study is on-going and results pending.

4.13 Tracking anadromous adult salmonids in Canada's three oceans to evaluate the sustainability of catch-and-release angling practices – behavioural and physiological perspectives on estuarine fisheries

From August 10th - Sept 12th, Jacqueline Chapman and two team members (Cooke lab Phd and MSc students Robert Lennex and Daniel Struthers) flew to Cambridge Bay, NU to test the effects of catch and release on Arctic charr migration survival and behaviour. In addition, biological samples were taken to provide the first profile of diseases in wild Arctic charr in Canada's north, and investigate the

relationship between pathogens and charr migration behaviour. Fish were captured via rod and reel during their annual migration back to freshwater to overwinter after spending 6-8 weeks in the ocean feeding during the summer. An array of 16 VR2W receivers were deployed along the migration route up Freshwater Creek to the Grenier Lake system, and fish were externally tagged with capped V7 tags. Receivers were placed in strategic choke holds and at 600m intervals to eliminate the requirement for boating and to ensure high detection efficiency in this relatively shallow, fast flowing system. Biological samples will be taken to Dr. Kristi Miller's lab in February of 2016 where they will be screened for microbe loads and expression of immune and osmoregulatory genes.

In addition, biological samples were collected from this year's group of non-anadromous charr in Grenier Lake to allow comparison of pathogens between the two populations of fish (individuals forgo this feeding migration during spawning years, which is every 4 years). This information may help explain why mature fish do not migrate to the ocean prior to spawning.

Freshwater Creek is a unique system that is located very close to the hamlet of Cambridge Bay. Once part of a commercial weir fishery, this population crashed in the 1970's-80's and a moratorium was placed on gill net and weir fishing to allow recover. The last enumeration of the Grenier Lake fall upriver migration was in 1991 and found ~40,000 individuals up from ~9000, and we were advised it was an appropriate system to conduct our work. During this season however, there appeared to be a drastic decline of charr compared to historical data and local ecological knowledge. We believe this may be a result of the increased exploitation of Freshwater Creek charr associated with the increased popuatlion of Cambridge Bay over the last two decades. Additionally, beneficiaries are allowed to extract fish from the system via snagging, an extremely effective method that removes a large number of fish per year. While the Hunting and Trapping Organization has locally banned snagging, it is general knowledge that this ban would not be upheld in Nunavut courts under the rights of Beneficiaries (i.e. indigenous peoples).

Fish moved through within a 3 day period in numbers estimated to be in the mid to high thousands, resulting in low catch rates via rod and reel. The permit was amended to allow for gill netting in the banned areas, however only 2 fish were caught in 10 hours of netting in the estuary of freshwater creek, and 2 caught for 16 hours of gill netting in "West Arm" of Cambridge Bay approximately 10 km from Freshwater Creek. Final sample size for acoustically tagged fish was 15, 11 collected from angling in the freshwater creek estuary, and 4 gill net within the estuary. One fish was recaptured, and one fish released within range of receivers was not tracked due to tag malfunction. This sample size is inadequate to investigate the objectives of this research, and though we were advised this system was appropriate for collection method of rod and reel, we no longer believe that to be the case.

4.14 Seasonal movements and spawning migrations of white sturgeon

Through partnering with a recreational fishing guide, we sampled adult white sturgeon from the catch and release fishery. All fish had a blood sample taken to measure stress hormones, and > 40 have been implanted with acoustic transmitters to study post-release behaviour in the lower Fraser River, BC. This tagging work was done on the lower Fraser River between Mission and Chilliwack, BC. Sturgeon were tagged with either V16 or V13 acoustic transmitters, and once released moved within the pre-existing Pacific Arena acoustic receiver array. We supplemented the array with additional acoustic receivers so as to increase coverage in key areas where spawning activity is known to occur (near Chilliwack). We also conducted stress tests in captive sturgeon at the US Fish and Wildlife Service's Abernathy Fish Technology Centre, where the physiological response to simulated angling stress was quantified -

providing important baseline information for interpreting the behaviour of sturgeon after angling stress in the wild. While physiological knowledge of this sort can provide a mechanistic understanding of stress responses, its usefulness to fisheries managers and stakeholders is limited. In an attempt to develop a series of best practices for the handling and release of angled sturgeon, and to provide simple, meaningful assessment of sturgeon condition after angling, we began the development of a reflex action mortality predictor index (RAMP), which is a method that assesses the presence or absence of natural, predictable reflexes in sturgeon after an angling event (e.g. attempt to escape when tail is grabbed, etc). Four to five simple reflexes can be assessed and then scored to produce a RAMP score. By correlating individual RAMP scores to the physiological (blood plasma) assessments from the same fish, we can ascribe a physiological stress condition to an angled fish based on it reflex responses. Our results are showing strong direct correlations between RAMP and glucose and lactate levels in blood plasma. Current work will test the efficacy of these RAMP scores in predicting post-release behaviour and fate in the wild.

4.15 Survival and movement rates of out-migrating juvenile Pacific salmon

Summarization and write-up of results from outmigrating smolt studies from 2010 to 2015 have been on-going and resulted to date in several technical reports and recently published manuscripts (eg Ecological Applications). In 2015, the lower Fraser River acoustic receiver array was re-deployed by Kintama Ltd and the upper Chilcotin acoustic receiver array was re-deployed by UBC. Both arrays had receivers positioned in identical locales to previous years. Marine OTN lines were in same locales as in previous years with additional ones deployed by Kintama through loans of equipment from OTN to the Pacific Salmon Foundation. At Chilko we tagged ~ 10 adult bull trout with V13 transmittters (complementing the 20-25 tags deloyed in previous years) in order to more closely examine predator movement and feeding patterns. Our recent work has shown that bull trout may account for large levels of smolt mortality during early depature from the natal lake. We are using a VPS positioning system involving ~20 receivers, in partnership with VEMCO, to assess. Because of unusually high flows, during April and May 2015, sockeye smolts could not be tagged from Chilko Lake because the DFO counting fence which is used to access smolts could not be deployed. As part of our new partnership with the Pacific Salmon Foundation, were were able to implant acoustic transmitters into 300 Seymour River steekhead smolts which were provided by a local hatchery. This site is situated only a short distance from Burrard Inlet and the Pacific Ocean. Fish were surgically implanted with V7 transmitters, in an identical fashion to sockeye in previous years. Small gill samples were collected from a subset of fish to quantify pathogen loads using newly developed molecular techniques (fluidigm qPCR). We will relate these data to acoustic detection data in the river and early marine environments. Steelhead smolts have a very similar marine migration route to sockeye so will provide an interesting comparison of survival and behaviour. The lower Fraser array will be downloaded by Kintama in early winter 2015. Some of the marine arrays have been downloaded by Kintama with the remainder being downloaded by OTN in mid-November. Assessments of survival and movement rates are pending the recovery of these receiver lines. Pathogen analyses will occur during winter/spring 2016.

We are taking two approaches to examine these multi-year datasets from a big picture perspective. The first is to utilize empirical statistical models to relate among-year and locale survivorship and behaviour to environment and fish characteristics (in progress). We have recently completed analyses comparing marine movement rates and directionality of movements of sockeye and steelhead smolts around and across the Northern Strait of Georgia OTN line - these data were just published in PloS-1. Our second approach is to develop a spatially-explicit individual based model for simulating survival and migration rates. This IBM framework has been adapted and will shortely be tested for use. Our goal is to use this

framework on different salmonid species and in different regions (e.g Chinook and Steelhead salmon from the Columbia River; Atlantic salmon from eastern Canada).

c) Significant deviations

Our goals, objectives and approaches remain consistent with what we described in our project specific proposals. There are no significant deviations.

However there was some difficulty in obtaining necessary sample sizes of Arctic charr in the north so we will need to return in 2016 for additional tagging. Despite valiant efforts of the team sent to the Arctic, the fish never materialized. We contracted local fishers and worked closely with DFO yet the fish were still elusive in the system. There is a great deal of potential to work alongside Fisheries and Oceans (Les Harris, Central and Arctic) in 2016 in another system where fish capture would be more reliable. Through this group there is currently an array set in the marine environment in nearby Wellington Bay, a strong relationship established with commercial weir fishers, and refined surgery platforms. Each year, Fisheries and Oceans accompanies commercial Inuit fishers to the weir sites to collect fish for sampling and/or tagging. Our group could leverage this relationship through providing support for DFO while also conducting experimental fishery simulations on fish collected in commercial weirs. This would ensure sample size adequate to reach objectives. Additionally, results from pathogen screens from different populations (Wellington Bay area rivers, Freshwater Creek, Jayco River to the East) may help managers distinguish between populations and/or understand the degree of mixing among stocks, which complements ongoing work by DFO using genetic screening. These potentials have been discussed and it is agreed that this would benefit both parties if we were to continue work next year.

There are also some new additional projects that we have been able to capitalize on, at no additional costs, along the same themes as our main objectives. This includes a project with DFO examining the effects of external vs internal tagging approaches on survival of maturing adult sockeye salmon. This project involves a field study on the Harrison River and a laboratory based holding study at the Cultus Lake Salmon Research Laboratory. We also ran a pilot study at the Cultus lab exploring the utility of new physiological and activity biologgers. Also we have recently partnered with the Canadian Fishing Company of Canada and several ENGOs launching a study this past summer examining the effects of commercial fishing handling practices on release of by-caught chum salmon. The success of this study from a stakeholder perspective has been huge and has opened additional research and funding opportunities for the coming few years which could serve as bridge funding for the Pacific OTN to move into a new OTN version 2. We also formed a partnership with the Pacific Salmon Foundation to provide funds for continued tagging of salmon smolts and studying their survival and behaviour through to 2018.

d) Coordination and integration

Adult Salmonid studies (Projects 4.12 and 4.13)

October 2014 to September 2015 – Eliason (RA) actively mentored Melissa Dick (MSc), Katrina Cook (PhD), Vanessa Minke-Martin (MSc), and Steve Healy (MSc) on Pacific salmon thermal tolerance and physiology, physiological and biochemical techniques (e.g. developing metabolite assays), experimental design, data collection, and scientific writing.

October 2014 to September 2015 – Bi-weekly meetings between Young, Nguyen, and Corriveau to discuss data cleaning, data analysis, and preparation of manuscripts from the Knowledge Mobilization data.

October 2014 to September 2015 – Martins (RA) and Braun (PDF) actively mentor Middleton (MSc) on data analysis and preparation of manuscripts

October 2014 to September 2015 - Eliason met with members of DFO EWatch (e.g. Patterson, Hills, Robinson) numerous times to discuss the results and implications of Pacific salmon experiments from 2014 and to plan the 2015 field season.

October 2014 to July 2015 – numerous meetings between Matt Drenner (PhD) and Kristi Miller (DFO collaborator, OTN PI) to discuss research relating genomic patterns of homing sockeye salmon in the ocean to marine survival.

October 2014 to August 2015 - Lotto had numerous meetings with Melissa Dick (Carleton), Tanya Prystay (Carleton/Dalhousie), Mike Lawrence (Carleton), Arthur Bass (UBC), Nathan Furey (UBC), Katrina Cook (UBC), Steve Healy (UBC), Matt Casselman (UBC), David Patterson (DFO), and Jayme Hills (DFO) regarding the planning, logistics, and experimental design of all the various field projects.

October 2014 to December 2014 – Chapman, Bass, Teffer, and Dick (all grad students) worked together and collaborated in the field

October 2014 to July 2015 – Braun (PDF) actively mentored Vanessa Minke-Martin (MSc) on study design, data analysis, and data presentation of telemetry data.

October 2014 to September 2015 – Eliason (RA) actively mentored Minke-Martin (MSc) on aspects of salmon physiology.

October 2014 to September 2015 – Martins (RA) had several meetings with Drenner (PhD), Furey (PhD), Middleton (MSc), Minke-Martin (MSc) and Teffer (PhD) to discuss study design and/or data analysis.

October 2014 to September 2015 – Middleton (MSc) met with Martins (RA) and Braun (PDF) on numerous occasions to continue analyses of Seton River radio-telemetry data and discuss results.

November 2014 to August 2015 Lotto had numerous telephone and face to face conversations with DFO personnel Jeffrey Lemieux, Bryan Smyth, Lucas Pon, and Garrett Lindin regarding logistics and planning of research that was to be conducted at the DFO Cultus Lake Salmon Research Laboratory (Tag effects study, Heart Rate Data Logger study)

November 17, 2014 – Cook (PhD) has a conference call with DFO Prince Rupert, NGO's (Watershed Watch, RainCoast Trust), and consulting (Fish First consulting) to discuss objectives of and priorities for 2015 North Coast chum research

November 4, 2014 – meeting at UBC between Minke-Martin (MSc) and Teffer (PhD) to discuss effects of thermal experience on pathogens and spawning.

December 2014 to May 2015 - Lotto had numerous telephone and face to face conversations with DFO managers Keri Benner, Gary Zwack, Brad Butler, and Ian Barnes regarding the planning and logistics of our Chilko Sockeye Smolt Study.

December 4, 2014 - Hinch, Cooke, Raby met at Carleton University to discuss past and future Pacific arena projects.

December 8, 2014 - Dick worked with DFO technicians (Taylor Nettles) at the West Vancouver DFO lab to analyse plasma samples.

December 9, 2014 – meeting (Minke-Martin (MSc), Hinch, Donaldson (RA), Patterson, and Dr. John Richardson – UBC Forestry) to discuss Minke-Martin thesis proposal, research progress to date, and guidance for 2015 analyses.

December 12, 2014 – meeting at UBC (Hinch, Casselman, Bett, Middleton, Burnett, Minke-Martin, Braun) to discuss research progress and report writing

December 15, 2014 – Cook (PhD) has a conference call with DFO Prince Rupert, NGO's (Watershed Watch, RainCoast Trust), and consulting (Fish First consulting) to discuss proposal produced for 2015 North Coast research

December 16, 2014 – meeting at UBC (Braun, Burnett, Middleton) and by phone (Minke-Martin) to discuss analysis of physiology data

December 19, 2014 – conference call to initiate strategic planning of upcoming Arctic work (Fisk, Les Harris (DFO), Mike Power, JS Moore, Chapman, Cooke)

January 15 to March 15, 2015 – Bass (PhD) analyzed sockeye RNA samples from the Adams River stock (collected in 2014) at the DFO Pacific Biological Station in Kristi Miller's laboratory. Provided guidance regarding laboratory techniques for PhD Jacqueline Chapman. Collaborated with PhD Nathan Furey on study of pathogen profile of Chilko Lake sockeye smolts consumed by bull trout. Ongoing meetings with PhD Amy Teffer to plan analysis of molecular data and integration of telemetry and holding studies.

January 15 – April 1 2015 - Cook, Teffer, Bass, Chapman (PhD grad students) collaborate with Dr. Kristi Miller and go to Pacific Biological Station to conduct genomic laboratory analysis using high-throughput qPCR

January to August 2015 – Bi-weekly meetings between Young (co-PI) and Nguyen (PhD) to discuss population frames and survey design for Nguyen's survey of international telemetry scientists.

January 12, 2015 – Preliminary discussions on statistical analysis of blood physiology data (Dick, Eliason, Patterson)

January 12, 2015 – Cook (PhD), Cooke, and Hinch discuss opportunities for North Coast research

January 13, 2015 – Cook, Chapman, Bass, and Teffer (all PhDs) plan sample processing to be conducted at the Pacific Biological Station

January 20, 2015 –Dr. Miller met with students Teffer, Cook, Bass and Chapman at the Pacific Biological Station, Nanaimo, BC to discuss experimental design for molecular analyses of tissue samples from 2014 studies.

February 5, 2015 – Middleton (MSc) met with DFO Patterson to discuss analyses and results from Seton River adult sockeye salmon radio-telemetry project.

February 5, 2015 – Presentation by Young (Co-PI) of preliminary findings from the Knowledge Mobilization study at to stakeholder attending the annual workshop organized by the Hinch lab at UBC, Vancouver.

February 12, 2015 – Meeting at PBS to discuss microbe screening and gene expression assays for 2014 coho field season (Miller, Chapman)

February 19, 2015 – Cook and Hinch meet with Canadian Fishing Company to propose partnership through an NSERC Engage grant. Cook gives a presentation on proposed work.

February to June 2015 – Bi-weekly meetings among UBC personnel (Hinch, Casselman, Middleton, Bett, Minke-Martin) to discuss the interpretation of results and research priorities for the August 2015 field season.

February - April 2015 – Training at PBS on equipment required to run microbe and genetic expression assays (Teffer, Bass, Cook, Chapman, Miller)

February 18, 2015 – Cook meets with Dr. Colin Brauner (UBC Zoology) to discuss hypotheses regarding ion regulation during the saltwater to freshwater transition that Pacific salmon are exposed to during migration

March 5, 2015 – Cook meets with Tony Farrell to discuss objectives of Pacific salmon holding study

March 10-17, 2015 – meetings at UBC (Hinch, Casselman, Bett, Middleton, Burnett, Minke-Martin, Braun) to analyze data and write papers

April 2, 2015 – Cook meets with Eliason to plan analyses to be conducted at West Vancouver DFO laboratory

April 3 2015 – meetings between Matt Drenner (PhD), Lisianne Hahn (PDF), and Nich Burnett (MSc) to discuss how to extend OTN Pacific salmon training and plan telemetry studies on catfish in the Amazon River.

April 28, 2015 – Bass met with PIs Scott Hinch, Kristi Miller, and Steve Cooke (phone) to discuss progress on PhD research and plans for field work in 2015.

May 15, 2015 – Bass met with PI Tony Farrell to discuss progress on PhD research and plans for field work in 2015.

May 15, 2015 - Eliason mentors Cook and Dick on methods to extract metabolites from salmon tissue samples at DFO West Vancouver Laboratory

June 2014 to August 2015 - Lotto had numerous conversations with Chris Cue (Canfisco) and Greg Taylor (Fish First Consulting) regarding the logistics of Katrina's Area 6 study.

June 8, 2015 – Cook, Eliason, Teffer, Bass and Hinch meet to plan logistics of upcoming field season

June 12, 2015 – Cook meets with managers from the Canadian Fishing company to hire boats to conduct 2015 research

June 16, 2015 – Cook meets with Bob Rezansoff, a commercial fisherman with the Canadian Fishing Company to discuss objectives of 2015 research

June 22-26, 2015 – Bett met with Dr. Hiroshi Ueda (Nitobe University) and his research group to discuss olfactory homing research.

June 23, 2015 – Cook meets with Barry Curic, a commercial fisherman with the Canadian Fishing Company to discuss objectives of 2015 research

June 24, 2015 – Cook meets with representatives of NGOs (Watershed Watch, Raincoast Trust, David Suzuki Foundation) to discuss their involvement with planned 2015 research and their objectives

June 25, 2015 – Cook meets at Canadian Fishing Company headquarters to meet with company executive, NGOs (Watershed Watch, Raincoast Trust, David Suzuki Foundation) to plan 2015 field research

July 6 – Cook meets with commercial fishermen and Canadian Fishing Company employees in Prince
July 9, 2015 – Cook meets with DFO collaborators in Prince Rupert to coordinate sampling efforts.

July 11, 2015 – Cook meets with representative from NGO Skeena Wild to coordinate logistics of field operations on the North Coast

July 12-15, 2015 – Meeting between Young, Cooke, and Hinch to discuss manuscripts in preparation from Knowledge Mobilization research.

July 15, 2015 – Brief meeting to discuss availability of telemetry equipment in Cambridge Bay (Fisk, Chapman)

July 16, 2015 – Meeting during the International Conference of Fish Telemetry to discuss upcoming Atlantic tagging projects on the East coast (Chapman, Lennox, Cooke, Martha Roberston)

August 2015 to September 2015 – numerous meetings between Matt Drenner (PDF), Collin Middleton (MSc), Art Bass (PhD), and Matt Casselman to discuss field planning and data analysis for salmon telemetry projects.

August 12, 2015 – Teffer advised Melissa Dick on laboratory and experimental design for holding studies eAugust 15, 2015 – Cook meets with DFO collaborators in Prince Rupert to exchange data collected and overview accomplishments of 2015 research

August 18, 2015 – Meeting in Portland, Oregon (concurrent with American Fisheries Society conference) to discuss bull trout predation on sockeye salmon smolts and bull trout movements (Furey, David Beauchamp).

September 21, 2015 – Teffer met with Patterson and DFO EWatch members to discuss information relevant to CSAS report currently underway regarding the effects of fisheries on adult migrating salmon

September 30, 2015 – conference call meeting with Kristi Miller (DFO collaborator, OTN PI), Nathan Furey (PhD), Arthur Bass (PhD), Steve Healy (MSc) Jacqueline Chapman (PhD), Katrina Cook (PhD) and Scott Hinch (OTN PI) to discuss laboratory approaches to upcoming genomic work at the DFO Pacific Biological Station in 2016.

September 21, 2015 – Teffer met with Martins at SFU to discuss methodology and analysis of pathogen monitoring data

Sturgeon study (Project 4.14)

October 2014 to September 2015 – numerous communications between Montana McLean (PhD) and Erin Stoddard (BC Provincial Biologist) related to collaborative acoustic telemetry network in Fraser River, BC for the purpose of tracking white sturgeon.

October 14, 2014 – McLean (PhD) meets with members of the sturgeon community working group, including First Nations of BC, the Fraser River Sturgeon Conservation Society, recreational and guided anglers associations, and provincial biologists to discuss areas of interest for white sturgeon studies in the Fraser River.

February 12, 2015 – McLean and Kyle Hanson (US Fish and Wildlife) meet to discuss data analysis for captive white sturgeon stress studies.

June 16, 2015 – initial meeting between McLean and Dan Baker (Vancouver Island University) to discuss experimental design and data collection for laboratory-based stress studies on captive white sturgeon.

July 12, 2015 – Vivian Nyguen (PhD) provides McLean with advice on developing surveys for white sturgeon anglers

August 12, 2015 – Meeting between McLean and Erin Stoddard to discuss receiver download schedule and placement.

Smolt and Juvenile Salmon study (Project 4.15)

March through April 2015 – Healy had several meetings with Hinch (OTN PI), Nathan Furey (PhD), Erika Eliasons (OTN Post-doc), Andrew Lotto, Steve Healy (MSc), Amanda Banet, Matt Drenner (PhD), Arthur Bass (PhD) to discuss plans for Chilko Lake sockeye smolt tagging in spring 2015.

March 11, 2015 – Meeting at UBC to discuss and plan Pacific salmon smolt research (Furey, Healy, Eliason, Mandy Banet, Andrew Lotto).

March 2015 – April 2015 – Furey (PhD) actively advised Healy (MSc) regarding Pacific salmon smolt telemetry field studies and surgery techniques.

April 1, 2015 – meeting at Simon Fraser University to discuss analyses of fine-scale movement data of sockeye salmon smolts and bull trout (Furey, Martins).

May 25, 2015 – Healy had several e-mails and phone calls exchanged between David Welch (Kintama), Erin Rechisky (Kintama), Steve Healy (MSc), Scott Hinch (OTN PI) and Stephen Vincent (Seymour Salmonid Society) to plan upcoming work up at the Seymour River tagging steelhead smolts.

September 15, 2015 – meeting at UBC to discuss Pacific salmon smolt research (Furey, Hinch, David Welch, Evgeny Pakhomov, Sarah Gergel).

September 30, 2015 – Skype meeting with David Welch (Kintama) and Steve Healy (MSc) to discuss future directions and collaboration with Seymour River steelhead marine data from 2015.

e) Scientific and/or engineering significance

1) We have now examined physiological and behavioural impairment in adult salmon resulting from various capture and release approaches (or capture/escape) in fisheries among five different species (in freshwater, estuaries, and oceans). The key results to date are that the amount of air exposure and physical injury directly relates to impairment, vitality and subsequent survival after release or escape from fishing gear. Further, approaches to help salmon recover from a capture event (e.g. assisted ventilation) has limited beneficial effects and may even be detrimental for aiding recovery and survival of released fish, except when a fish is extremely physiologically impaired. RAMP measures have proven to be highly predictive of delayed mortality in sockeye and coho salmon in riverine environments thus these simple and quick reflex measures could be used by fishers as a means of knowing whether they should release by-caught salmon, or keep them because they will die anyway during subsequent migration. The results of all these studies can help managers assess how different fishing handling and release strategies in coastal and estuarine zones influence salmon behaviour and survival. We have completed one of the largest qualitative Knowledge Mobilization studies performed on a single sector, and certainly the largest yet completed in Canada. Findings will have immediate practical application for OTN scientists, and for partners within DFO and among stakeholder groups. One of the astonishing results was that DFO managers are unwilling, despite our close collaborations with them, to utilize many of our specific telemetry results where post-release mortality rates are assessed, primarily because there is no simple mechanism for such results to be adopted into the current management structure. Managers recommended, and we are now preparing, a CSAS review document which will provide specific guidelines and ways to interpret our mortality rates that can be readily used by managers. Nonetheless, our knowledge studies have found that some key stakeholders and users (> 2/3rd of First Nations fishers) trusted the results of telemetry science and felt positively about how it could help fisheries management.

2) We have completed the largest experimental field study on assessing swimming activity and physiology to delayed migration mortality which involves acoustic accelerometry, detailed measures of the riverine hydrodynamics using ADCP, and experimental flow releases from a hydro dam. Results indicate that burst swimming is required to pass through areas of turbulent flow; however fish that burst swam the most were least likely to reach natal areas after passing the turbulent zone - particularly for females, indicating strong latent effects of anaerobiosis with mortality likely caused by tissue specific oxygen debt and cardiac falure. This is the first such examination of its kind and is helping reveal how swimming performance is affected by water flow dynamics in a field setting.

3) This year we continued with telemetry and holding studies examining delayed mortality in adult salmon released from estuarine and ocean fisheries, and the first ever assessment of delayed mortality in chum salmon and Arctic charr. This year we published additional work examining coho salmon 'by-catch' following tagging and release from a commercial marine purse seine fishery. We found that released coho can survive at rates (~ 80%) which far exceed those currently applied in management models (~ 20%) for dealing with released coho bycatch mortality – this type of information can be used to assist fisheries managers in revising allocations, timing and locations of marine salmon fisheries that may intercept endangered stocks of coho.

4) Our juvenile salmon tracking projects have yielded some outstanding results. First, we recently published a 5 year summary of patterns of survival and movement behaviour in outmigrating sockeye smolts, traversing > 1000 km distance from rearing areas to the open ocean - high levels of mortality were observed in clear water areas near the start of the migration, and appear to be related to predation by bull trout. Second, we have learned that the high levels of observed mortality in early freshwater migratory areas is correlated to the presence of specific pathogens that fish are carrying, and pathogen analyses of predator stomach contents indicates preferrential injestion of pathogen-laden fish.

5) The microbe monitoring platform we have recently developed and evaluated makes it possible to assess the presence and load of 46 salmon pathogens on non-destructively sampled tissue from tagged fish. We have recently performed validations showing the sensitivity, specificity and repeatability of results from this platform providing assurance that the data produced are of high quality and accuracy. This broad pathogen screening provides novel and comprehensive data on the microbiome of returning adult salmon in the Fraser, identifies shared and unique microbes among species within and across years, and offers baseline information on pervasiveness and potential for pathogenicity of various infectious agents. This platform may very well revolutionize our understanding of the role of pathogens, and more explicitly, co-infections, on wild salmon performance. Using laboratory studies, we have found several microbes including Ichthyophthirius multifiliis and Parvicapsula minibicornis to increase in load with the duration of freshwater residence and this effect was amplified at high water temperature. Preliminary results from field telemetry studies in both smolts and adults indicate that presence of certain pathogens and pathogen loads are predictive of migration survival. Specifically, survival of Chilko sockeye smolts to reach the ocean was related to the presence of the IHN virus; a newly discovered virus in BC, the Piscine Reovirus, and microspordian parasite Loma salmonae were correlated with upriver migration survival in adult Chilko sockeye.

6) White sturgeon in the lower Fraser River are listed as threatened under the Species at Risk Act of Canada, yet beyond mandatory catch-and-release, there are few regulations on angling activity. A typical angling event can last upwards of 1 hour, which is an enormous stress. RAMP, or reflex action mortality predictors, is a method for method for scoring the presence or absence of natural reflexes as a proxy for post stress state or condition. Using a population of sturgeon at the Abernathy Fish Hatchery in Washington State, we have linked RAMP scores to physiological indicators of stress (plasma lactate and glucose levels) and recovery times. A manuscript is in final stages of preparation and will be submitted for peer review by the end of 2015. Our aim is then to use acoustic telemetry and RAMP to predict the fate of wild caught sturgeon on the Fraser River in 2016. Additional ongoing work includes the analysis of seasonal/temperature dependent links between post-angling physiology and fate in Fraser River white sturgeon, and size and age related differences in the physiological stress response using captive white sturgeon at Vancouver Island University.

f) Significance of research to the community/public

In Canada, fish have significant socio-economic significance - they support livelihoods, contribute to food security, provide leisure opportunities, and directly relate to the culture of aboriginal peoples. Our work conducted under the auspices of OTN Canada is "partner" research and involves substantial interaction with stakeholders and governments (responsible for managing fish on behalf of the public trust) and is inherently "applied". Much of the science we conduct is in direct support of management and conservation, most often with the questions tackled being ones proposed by stakeholders and government. In many cases our research is the only science available and thus is filling an important void. Through careful experimentation in the lab and field we have been able to reduce management uncertainty in areas related to climate change and fish migration, disease development and fisheries interactions.

7. Difficulties encountered

☒ Scientific problems/difficulties

For project 4.13 we had difficulties in capturing Arctic char as described above. Fish catch rates were low despite using local indigenous and government knowledge. We are confident that this work can be completed in 2016 with the existing budget planned for 4.13 and a small carryover from 2015. The carryover will be related to the fact that we spent fewer dollars hiring local fishers given that absence of fish in 2015. Quite simply, it did not make sense to have fishers actively fishing when there was no sign of fish in the stream (which has ultra-clear water).

8. Networking and outreach

a) Intra-network collaboration and partner meetings

October 26, 2014 – K. Miller (Pacific Arena) conducted genomic analyses on Atlantic salmon tissue samples provided by Ian Fleming (Atlantic Arena) to assess both microbes and gene expression – an example of how Pacific technology is being applied to Atlantic studies

January to September 2015 – Young, Hinch, Cooke participated in the OTN futures committee, including conference calls and face-to-face meetings in Vancouver and Halifax, and by teleconference.

February 2015 – Martins (Pacific Arena), Sara Iverson and Fred Whoriskey participated in the telemetry workshop held during an annual conference organized by the Brazilian Society of Ichthyologists. Martins contribution involved a presentation synthesizing the salmon telemetry studies that have been conducted under OTN Pacific Arena and answering participants questions on the benefits and challenges of a telemetry network at the end of the workshop.

February 2015 – Dick and Chapman (Pacific Arena) accompanied Dr. Sara Iverson (OTN HQ) at the NSERC Ocean Kiosk event on Parliament Hill, Ottawa, ON

May to October 2015 – Eliason, Ngyuen, Martins (Pacific Arena) joined the IdeasOTN (Integrate Describe Expand And Synthesize OTN) committee and participated in several conference calls to determine the committee's objectives and plan synthesis manuscripts; currently involved in two synthesis projects being conducted in collaboration with other OTN members.

May to October 2015 – Chapman (Pacific Arena) collaborating with Arctic Arena (Aaron Fisk; and others) bringing Pacific technology/approaches to tagging studies involving capture release research on arctic char; also involved collaboration between Chapman and Les Harris (DFO Central and Arctic regions).

July 12-15, 2015 – numerous meetings and planning sessions with Young, Hinch, Cooke, Iverson, Whoriskey, and others regarding future OTN activities during the Halifax ICFT meetings.

July 14, 2015 – Young and Cooke met with representatives from GLATOS to discuss potential Knowledge Mobilization research on telemetry work in the Great Lakes modelled after OTN Pacific research program.

July 15, 2015 – meeting at Dalhousie University (in conjunction with ICFT conference) to discuss and plan initial steps of meta-analysis involving OTN from all arenas and internationally of aquatic/marine animal movement rates using biotelemetry data collected globally (Furey, Kessel, Yurkowski, Martins, Hussey).

July 16, 2015 – meeting in Halifax (concurrent with ICFT conference) between Pacific and Atlantic arena investigators to discuss analysis of fine-scale movements of salmon smolts and (Furey, Martins, Auger-Méthé)

July 20, 2015 – K. Miller (Pacific Arena) provided a report to Fred Whoriskey (Atlantic Arena) on microbe analysis of Atlantic salmon smolts which have since led to further collaboration between their laboratories under the Genome BC Strategic Salmon Health Initiative.

September 2, 2015 – Conference call among Pacific investigators and OTN HQ to discuss database management issues involving citations of research using acoustic, satellite, or radio telemetry (Furey, Auger-Methe, Pye, Rounds, Ryan).

September 2015 – Martins, Auger-Methe and Sopinka initiated email discussion on the potential of developing a podcast series for OTN as part of ideasOTN. Sopinka and Minke-Martin had a conference call to further discuss the development of a podcast series for OTN.

b) Interaction/Outreach to Broader Community

October 2014 to September 2015 - Cook participates in monthly planning calls as a member of the executive committee of the Washington-British Columbia chapter of AFS

November 19, 2014 – Miller was invited to a First Nations Fisheries Council workshop (open to First Nations only) to provide an overview of the state of our knowledge on the role of disease in survival of wild salmon which included the tracking research performed under the OTN. She also sat on a panel discussion on future directions of research, where again the ability to track fish to determine fate was discussed.

December 9, 2014 – Dick visited Lucerne Elementary Secondary School in New Denver, BC, and led a discussion and hands-on activity on the physiology of Pacific salmon with grade 7/8 and 9/10 classes

December 10, 2014 – Miller attended the BC Salmon Farmers Association workshop and participated in discussions on research priority setting which included the potential use of biotelemetry, as exemplified

by the OTN project, and microbe monitoring, as exemplified by the OTN linked and leveraged Strategic Salmon Health Initiative project.

January to September 2015 – Numerous telephone, skype, and email exchanges by Young regarding Knowledge Mobilization research with stakeholders in the Pacific Salmon Foundation and the Secwepemc Fisheries Commission.

January 6, 2015 - Donaldson was invited as a Panel Speaker at the 67th Canadian Conference for Fisheries Research in Ottawa, Ontario.

January 14, 2015 – Presentation by Teffer to the Pacific Salmon Commission on the impacts of fisheries capture and handling on disease processes and survival of released salmon bycatch in the Fraser River

February 5, 2015 – Hinch hosted and organized the 9th annual workshop on salmon tracking, capture fisheries and climate change at UBC; presentations were made by a dozen graduate and postdoctoral students on current research to ~60 attendees representing government agencies, First Nations fisheries managers, ENGOs, fisheries stakeholders, industry scientists.

February 6, 2015 – McLean, Crossin, Cooke and Hinch hosted a workshop at UBC to review the white sturgeon tagging project and related projects. In attendance were the following guests: Erin Stoddard (Ecosystem Biologist with BC Fish and Wildlife), Dave Robichaud (Fisheries Ecologist with LGL Limited consulting), Duane Jesson (Senior Fish Biologist with BC Fish and Wildlife), David Patterson (DFO researcher), Steve McAdam (BC Ministry of Environment), Dan Baker (Post-doc at the International Centre for Sturgeon Studies at Victoria Island University), and Sarah Schreer (Fraser River Sturgeon Conservation Society.

February 17, 2015 - Sopinka organized a science communication symposium for the American Fisheries Society Washington-British Columbia Chapter Annual Meeting which took place in Richmond, British Columbia. OTN member Minke-Martin contributed an oral presentation to the symposium. The symposium was featured in the American Fisheries Society's magazine, Fisheries (Sopinka, 2015; Fisheries 40(5), 240).

Feb 2015 - Cooke delivers two presentations at the Ottawa Sportsman's Show focused on the science and practice of catch-and-release fishing.

March 2015 – Dick created and submitted a 60-second video to the NSERC Science, Action! video contest titled "Tracking Migrating Pacific Salmon: The Effects of Telemetry Tags" generating more than 1000 views [https://www.youtube.com/watch?v=THZfUHFk6A8]

March 3, 2015 – Miller met with the Tula foundation to discuss the Strategic Salmon Health Initiative, an OTN linked and leveraged project; this meeting ultimately led to the development of a new collaboration. OTN-related microbe research was among the items discussed.

March 5, 2015 – Miller met with MP Weston in Vancouver to discuss the Strategic Salmon Health Initiative, an OTN linked and leveraged project.

March 20, 2015 – Furey presented results of Chilko sockeye smolt telemetry research at the annual Tsilhqot'in Nation Government Fisheries Forum in Williams Lake, British Columbia. Also in attendance were Steve Healy (MSc) and Andrew Lotto.

April 2, 2015 – Furey and Bett discussed salmon research at UBC with high school students enrolled at Explorations Academy.

April 23, 2015 – Cook is invited to attend and present at Skeena Fisheries Commission technical meeting in Terrace, BC. Andrew Lotto also attends.

May to July 2015 – Several e-mail, phone and personal discussions between Steve Healy (OTN HQP, MSc) and Stephen Vincent (Seymour Salmonid Society) to co-ordinate and talk about Seymour River steelhead smolt tagging.

May 2015-August 2015 - Cook regularly conducts interviews with commercial salmon fishermen from British Columbia to understand their perspectives on bycatch issues within the fishery and disseminate relevant research findings on post release mortality in Pacific Salmon

May 2015-August 2015 - Cook collaborated with NGO RainCoast Trust to mentor an intern from the Masters of Marine Management program at Dalhousie University

May 8, 2015 – Miller was an invited speaker at a Genome BC outreach workshop where she discussed the need for early engagement of managers and regulators who may be end-users of applied research.

May 23, 2015 – Bett gave a tour of the aquatic laboratory in the Faculty of Forestry at UBC for incoming undergraduate students

June 2, 2015 – Hinch, Casselman, and Minke-Martin attended the 2015 Bridge River Generating Complex Water Use Planning Workshop hosted by St'át'imc Eco Resources. Hinch presented telemetry results to representatives from St'át'imc Eco Resources, BC Hydro, private consultants, and the St'át'imc community.

July 7, 2015 – Cook meets with Gitaga'at Gurdian head Charter Patrol to overview objectives for research to be conducted on Gitaga'at territory

July 12, 2105 – Cook meets with science director from the Gitga'at Nation to overview objectives for research to be conducted on Gitaga'at territory

July 13, 2015 – Sopinka organized and led a science communication workshop at the 3rd International Conference on Fish Telemetry in Halifax, Nova Scotia.

June 17, 2015- Lotto and Cook met with Bob Rezanoff (Canfisco) to discuss Area 6 project.

July 24, 2015 – Lotto and Art Bass met with Chief Norma Webb and Clifford Peters of the Peter's First Nations to discuss upcoming telemetry work and how to involve Band members in the research.

August – September 2015 – Relationship building between Carleton University and Kitikmeot Region Hunters and Trappers Association (Chapman)

August 19, 2015 - Sopinka co-organized a science communication symposium for the 145th American Fisheries Society Annual meeting which took place in Portland, Oregon. OTN members, Sopinka, Minke-Martin and Nguyen contributed oral presentations to the symposium. The symposium was featured on PLOS Blogs (http://blogs.plos.org/scicomm/2015/08/31/fisheries-science-meets-scicomm-to-tweet-or-not-to-tweet/).

August 20, 2015 – Cook presents at Canadian Fishing Company head office to reveal preliminary results from field research

August 27, 2015 – Chapman met with the Board of Directors of the Kitikmeot Hunters and Trappers Association and Fisheries and Oceans officers in Cambridge Bay

September 2, 2015 – Miller participated in discussions at a DFO-NGO meeting on aquaculture/disease related research where some of the OTN-related research linking microbe data with salmon fate was discussed.

9. Dissemination of information and results

a) Refereed journal articles (17 total) – accepted/published

Bett, N.N., and Hinch, S.G. 2015. Attraction of migrating adult sockeye salmon to conspecifics in the absence of natal chemical cues. Behavioral Ecology 26(4):1180-1187

Bett N.N., and Hinch, S.G. 2015. Olfactory navigation during spawning migrations: A review and introduction of the Hierarchical Navigation Hypothesis. Biological Reviews. In press. DOI 10.1111/brv.12191

Burnett, N.J., Hinch, S.G., Braun, D.C., Casselman, M.T., Middleton, C.T., Wilson, S.M., Cooke, S.J. 2014. Burst swimming in areas of high flow: delayed consequences of anaerobiosis in wild adult sockeye salmon. Physiological and Biochemical Zoology 87(5):587-598.

Clark, TD, NB Furey, EL Rechisky, MK Gale, KM Jeffries, AD Porter, MT Casselman, AG Lotto, DA Patterson, SJ Cooke, AP Farrell, DW Welch, and SG Hinch. 2015. Tracking the migration of wild sockeye salmon smolts to the ocean reveals distinct regions of nocturnal movement and high mortality. Ecological Applications. In press.

Cook, K.V., R.J. Lennox, S. G. Hinch, and S. J. Cooke. 2015. Fish out of water: How much air is too much? Fisheries. 40 (9): 452-461.

Donaldson, M.R., S.G. Hinch, C.D. Suski, A.T. Fisk, M.R. Heupel, and S.J. Cooke. 2014. Making connections in aquatic ecosystems with acoustic telemetry monitoring. Frontiers in Ecology and the Environment 12:565-573.

Drenner, S.M., S.G. Hinch, E.G. Martins, N.B. Furey, T.D. Clark, S.J. Cooke, D.A. Patterson, D. Robichaud, D.W. Welch, A.P. Farrell, R.E. Thomson. 2015. Environmental conditions and physiological state influence estuarine movements of homing sockeye salmon. Fisheries Oceanography, 24: 307-324.

Eliason, E.J., A.P. Farrell. 2015. Oxygen uptake in Pacific salmon: When ecology and physiology meet. Journal of Fish Biology In Press.

Furey, NB, SP Vincent, SG Hinch, and DW Welch. 2015. Variability in migration routes influences early marine survival of juvenile salmon smolts. PLoS ONE 10(10): e0139269.

Furey, NB, SG Hinch, AG Lotto, and DA Beauchamp. 2015. Extensive feeding on sockeye salmon Oncorhynchus nerka smolts by bull trout Salvelinus confluentus during initial outmigration into a small, unregulated, and inland British Columbia river. Journal of Fish Biology 86(1):392-401.

Jeffries, K.M., Hinch, S.G., Gale, M.K., Clark, T.D., Lotto, A.G., Casselman, M.T., Li, S., Rechisky, E.L., Porter, A.D., Welch, D.W., Miller, K.M. 2014. Immune response genes and pathogen presence predict migration survival in wild salmon smolts. Molecular Ecology 23:5803-5815.

Raby, G.D., S.G. Hinch, D.A. Patterson, J.A. Hills, L.A. Thompson, and S.J. Cooke. 2015. Mechanisms to explain purse seine bycatch mortality of coho salmon. Ecological Applications 25:1757-1775.

Raby, G.D., M.R. Donaldson, S.G. Hinch, T.D. Clark, E.J. Eliason, K.M. Jeffries, K.V. Cook, A. Teffer, A.L. Bass, K.M. Miller, D.A. Patterson, A.P. Farrell, and S.J. Cooke. 2015. Fishing for effective conservation: context and biotic variation are keys to understanding the survival of Pacific salmon after catch-and-release. Integrative and Comparative Biology 55:554-576

Raby, G.D., S.M. Wilson, D.A. Patterson, S.G. Hinch, T.D. Clark, A.P. Farrell, and S.J. Cooke. 2015. A physiological comparison of three techniques for reviving sockeye salmon exposed to a severe capture stressor during upriver migration. Conservation Physiology doi:10.1093/conphys/cov015.

Raby, G.D., T.D. Clark, A.P. Farrell, D.A. Patterson, N.N. Bett, S.M. Wilson, W.G. Willmore, C.D. Suski, S.G. Hinch, and S.J. Cooke. 2015. Facing the river gauntlet: understanding the effects of fisheries capture and water temperature on the physiology of coho salmon. PLOS ONE 10:e0124023

Robinson, K.A., Hinch, S.G., Raby, G.D., Donaldson, M.R., Robichaud, D., Patterson, D.A., and Cooke, S.J. 2015. Influence of post-capture ventilation assistance on migration success of adult sockeye salmon following capture and release. Transactions of the American Fisheries Society 144:693-704.

Sopinka, N., Hinch, S., Healy, S., Harrison, P., Patterson, D. 2015. Egg cortisol treatment affects the behavioural response of coho salmon to a conspecific intruder and threat of predation. Animal Behaviour. 104: 115-122. *Article was chosen by the Editors as a Featured Article (Mother Courage, Animal Behaviour 104: iii-iv).

b) Refereed journal articles (6 total) – submitted

Burnett, N.J., S.G. Hinch, N.N. Bett, D.C. Braun, M.T. Casselman, S.J. Cooke, A. Gelchu, S. Lingard, C.T. Middleton, V. Minke-Martin, and C.F.H. White. In review. Reducing carryover effects on migration and spawning success of salmon through a management experiment of dam flows. Ecological Applications.

Nguyen, V.M., Young, N., Hinch, S.G., and S.J. Cooke. In review. Getting past the blame game: convergence and divergence in perceived threats to salmon resource among anglers and indigenous fishers in Canada's lower Fraser River. Submitted to Ambio.

Sopinka, N., Hinch, S.G., Healy, S.J., Raby, G.D., Patterson, D.A. In review. Effects of experimentally elevated egg cortisol on offspring traits in two species of wild Pacific salmon. Submitted to Environmental Biology of Fishes.

Sopinka, N., Jeffrey, J.D., Burnett, N.J., Patterson, D.A., Gilmour, K.M., Hinch, S.G. In review. Maternal programming of offspring hypothalamic–pituitary–interrenal axis in wild sockeye salmon (Oncorhynchus nerka). Submitted to General and Comparative Endocrinology.

Sopinka, N.M., Hinch, S.G., Healy, S.J., Raby, G.D., Patterson, D.A. Egg glucocorticoids differentially influence morphology and swimming performance among species and populations of wild Pacific salmon. In review Oecologia.

Young, N. Comparing knowledge mobilization across large research networks: the role of audience, institutions, and context in the reception and use of academic science. Science Communication. Submitted

d) Conference presentations (45 total) – contributed

Banet, A.I., Healy, S.J., Eliason, E.J. and S.G. Hinch 2015. Maternal effects of migration stress on juvenile Pacific salmon swimming performance. Pacific Ecology and Evolution Conference. Bamfield, British Columbia. February 28, 2015.

Bett, N.N, and Hinch, S.G. Attraction of Migrating Adult Sockeye Salmon to Conspecifics in the Absence of Imprinted Cues. American Fisheries Society Annual Meeting 2015. Portland, OR, USA. August 17, 2015.

Bett N.N., S.G. Hinch. 2015. Conspecific attraction during the spawning migration of sockeye salmon. American Fisheries Society Washington-British Columbia Chapter Annual General Meeting, Richmond, Canada.

Burnett, N.J., and S.G. Hinch. Reducing carryover effects on migration and spawning success of sockeye salmon through a management experiment of dam flows. Annual General Meeting of the American Fisheries Society, Portland, Oregon, August 16-20, 2015

Carvalho, F. M., Freitas, C. E. C., Forsberg, B., Power, M. Castello, L. and Martins, E. G. Arapaima (Arapaima sp.) trophic ecology in ria lakes and floodplain lakes in the Central Amazon. XXI Encontro Brasileiro de Ictiologia, Recife, PE, Brazil. February 2015.

Chapman, J.M., A.L. Bass, A.K. Teffer, D. Patterson, S. Hinch, and S.J. Cooke. 2015. Migration success and microbial communities of coho salmon released from simulated angling and gill net fisheries. International Conference of Fish Telemetry, Halifax NS. poster

Cook, KV . Raby GD, Nguyen, VM, Drenner, SM, Hinch, SG, Cooke, SJ, Patterson, DA. 2015. Post-release mortality of Interior Fraser River coho salmon. Contributed. Salmon Ocean Ecology Meeting. Victoria, BC., March 25-16, 2015

Cooke, S. J., Struthers, D., Martins, E. G., Gutowsky, L. F. G., Power, M., Doka, S., Dettmers, J., Crook, D., Lucas, M. C., Holbrook, C. M. and Krueger, C. C. A moving target: spatial ecology of fish,

biological assessment and management. 3rd International Conference on Fish Telemetry, Halifax, NS, Canada. June 2015.

Dick, M. July 13-17, 2015. Poster. Comparison of gastric and external radio transmitters on the physiology and survival of adult Pacific salmon. 3rd International Conference on Fish Telemetry (ICFT) / 5th Annuals OTN Canada Symposium. Halifax, Nova Scotia

Eliason. E., Patterson, D. A., Cooke, S. J., Farrell, A. P., Martins, E. G. and Hinch S. G. Fraser River salmon in an era of climate change. American Fisheries Society 145th Annual Meeting, Portland, OR, USA. August 2015.

Farrell, A.P. 2015. Oxygen- and capacity-limited thermal tolerance in fish. Society of Experimental Biology, Prague July 2015.

Furey, NB. 2015. What moves you? A proposed meta-analysis on the limits of aquatic animal movement rates. OTN Futures Meeting, as part of the International Conference on Fish Telemetry. Halifax, Nova Scotia. July 12, 2015.

Furey, NB, SG Hinch, DA Beauchamp, M Mesa, A Bass, V Minke-Martin, AG Lotto. 2015. Adult bull trout exhibit binge-feeding across temperatures during an annual prey pulse of juvenile sockeye salmon. Annual Meeting of the American Fisheries Society (AFS). Portland, Oregon. August 20, 2015.

Furey, NB, SP Vincent, SG Hinch, DW Welch. 2015. Variability in migration routes influences early marine survival of juvenile salmon smolts. International Conference on Fish Telemetry. Halifax, Nova Scotia. July 13, 2015.

Furey, NB, SP Vincent, SG Hinch, DW Welch, EL Rechisky, and M Melnychuk. 2015. Variability in migration routes influences early marine survival of juvenile salmon smolts. Annual meeting of the WA-BC Chapter of the American Fisheries Society. Richmond, British Columbia. February 18, 2015.

Hahn, L., Martins, E. G., Câmara, L. F., Garrone-Neto, D., Nunes, L. D. and Machado, L. S. Migratory movements of large catfish in the Xingu and Madeira Rivers (Amazon) revealed by combined acoustic and radio telemetry. 3rd International Conference on Fish Telemetry, Halifax, NS, Canada. June 2015.

Hahn, L., Martins, E. G., Câmara, L. F., Nunes, L. D. and Machado, L. S. Fishway passage and movement of giant migratory catfish downstream of a dam in the Amazon (translated title). XXI Encontro Brasileiro de Ictiologia, Recife, PE, Brazil. February 2015.

Hahn, L., Martins, E. G., Câmara, L. F., Garrone-Neto, D., Nunes, L. D. and Machado, L. S. Movement of giant catfish in the Xingu River revealed by combined acoustic and radio telemetry (translated title). XXI Encontro Brasileiro de Ictiologia, Recife, PE, Brazil. February 2015.

Healy, S.J., Hinch, S.G., Jeffries, K.M., Furey, N.B., Clark, T.D., Rechisky, E.L., Porter, A., Welch, D.W., Miller, K.M., Cooke, S.J., Farrell, A.P. Assessing the relationship between physiological condition and marine survival and behaviour in sockeye salmon (Oncorhynchus nerka) and

steelhead (O. mykiss) smolts. Poster presented at: the International Conference on Fish Telemetry; 2015 July 11-18th; Halifax, N.S.

Juanes, F., Teffer A.K., Miller K., Jeffries K., Patterson D., Farrell A., Cooke S., Hinch S. 2015. Stress and disease susceptibility of wild adult Pacific salmon. Advances in the Population Ecology of Stream Salmonids, Girona, Spain, May 28, 2015

Martins E.G., S.G. Hinch, S.J. Cooke, A.P. Farrell, K.M. Miller, K. M. A synthesis of salmon tracking studies in the OTN Pacific Arena. XXI Encontro Brasileiro de Ictiologia. Symposium on Telemetry and Mark-Recapture of Fishes. Recife, Brazil. February 6, 2015.

Martins, E. G., Patterson, D. A., Bradford, M., Grant, S., Moore, J. W. and Power, M. A life-cycle modeling approach to investigate cumulative effects on Fraser River sockeye salmon dynamics. American Fisheries Society 145th Annual Meeting, Portland, OR, USA. August 2015.

McLean, M.F., Litvak, M., Hinch, S., Cooke, S., Crossin, G. 2015. Physiological and behavioural impacts of C&R angling on white sturgeon in the Fraser River, B.C. The 3rd International Conference for Fish Telemetry. Halifax, N.S. July 13-17, 2015.

McLean, M.F.,Litvak, M., Hinch, S., Cooke, S., Crossin, G. 2014. Understanding the consequences of recreational angling stress on the biology and movement of white sturgeon in the Fraser River, BC. The 5thInternational Bio-logging Science Symposium, Strasbourg, France. September 2014. (Poster)

Middleton, C.T., N.J. Burnett, D.C. Braun, E.G. Martins, V. Minke-Martin, M.T. Casselman, S.G. Hinch. 2015. Pacific salmon migration through a regulated river; effects of dynamic migratory conditions and hydropower generation. American Fisheries Society Washington-British Columbia Chapter Annual General Meeting. Richmond, British Columbia. February 18, 2015.

Middleton, C.T., N.J. Burnett, D.C. Braun, E.G. Martins, V. Minke-Martin, M.T. Casselman, S.G. Hinch. 2015 Adult Sockeye salmon migration through the Seton hydrosystem. 3rd International Conference on Fish Telemetry / Ocean Tracking Network Annual Symposium. Halifax, Nova Scotia. July 16, 2015.

Middleton, C.T., N.J. Burnett, D.C. Braun, E.G. Martins, V. Minke-Martin, M.T. Casselman, S.G. Hinch. 2015 Adult Sockeye salmon migration through the Seton hydrosystem. American Minke-Martin, V., Hinch, S. G., Braun, D. C., Burnett, N. J., Martins, E. G., Middleton, C. T. and Patterson, D. A. Thermal experience of adult migrating sockeye salmon in a regulated watershed. 3rd International Conference on Fish Telemetry, Halifax, NS, Canada. June 2015.

Minke-Martin, V. 2015. Fishing for stories: Sharing research with new audiences through storytelling. Invited to give an oral presentation in the Science Communication Symposium at the American Fisheries Society Washington-British Columbia Chapter Meeting in Richmond, BC. (February 2015)

Minke-Martin, V., Braun, D.C., Burnett, N.J., Casselman, M.T., Eliason, E., Martins, E.G., Middleton, C.T., Patterson, D.A., Hinch, S.G..2015. Thermal experience of sockeye in a regulated river system. 3rd International Conference on Fish Telemetry / Annual Ocean Tracking Network Canada Symposium, Halifax, NS. (July 2015)

Minke-Martin, V. 2015. Fishing for stories: Sharing research with new audiences through storytelling. Invited to give an oral presentation in the Science Communication Symposium at the American Fisheries Society Meeting in Portland, Oregon. (August 2015)

Nguyen, V.M., Young, N., Hinch, S.G., and Cooke, S.J. 2015. Lessons learned in science communication: interactions with Fraser River stakeholders. American Fisheries Society 145th Annual Meeting, Portland, Oregon, August 16-21, 2015.

Nguyen, V.M., Corriveau, M., S.J. Cooke, S.G. Hinch, and Young, N. 2014. Knowledge Mobilization: Moving Scientific Knowledge into Pacific Salmon Fisheries Management. Pathways 2014: Common Futures. Integrating Human Dimensions into Fisheries and Wildlife Management. Estes, Colorado, USA, Oct 5-9, 2014.

Nguyen, V.M., Lynch, A.J., Young, N., Beard, D.T., Taylor, W.D., Coux, I.G., and Cooke, S.J. (Jan 26-28, 2015) "When water is more than water: Using a social-ecological watershed framework for inland fisheries management" at the Global Conference on Inland Fisheries, Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy.

Rechisky, EL, DW Welch, AD Porter, MK Gale, TD Clark, NB Furey, and SG Hinch. 2015. Telemetry-based estimates of early marine survival and travel time of juvenile Fraser River sockeye salmon in the Strait of Georgia and to Queen Charlotte Sound. Salmon Ocean Ecology Conference. Victoria, British Columbia. March 26, 2015.

Rechisky, EL, DW Welch, AD Porter, MK Gale, NB Furey, and SG Hinch. 2015. Telemetry-based estimates of early marine survival and travel time of juvenile Sockeye salmon in the Strait of Georgia and Queen Charlotte Strait, 2014. CSAS State of the Pacific Ocean. Nanaimo, British Columbia. March 11, 2015.

Rechisky, E.L., D.W. Welch, A.D. Porter, T.D. Clark, M.K. Gale, N.B. Furey, S.G. Hinch. 2015. Juvenile sockeye mortality and residence time in the Strait of Georgia and to northern Queen Charlotte Strait. Annual meeting of the WA-BC Chapter of the American Fisheries Society. Richmond, British Columbia. February 18, 2015.

Sopinka, N. 2015. Science communication tools to add to your telemetry toolbox. 3rd International Conference on Fish Telemetry, Halifax, Nova Scotia, Canada. July 16, 2015.

Sopinka, N. 2015. Staying Creative so the Science Doesn't Stale. American Fisheries Society Annual Meeting, Portland, Oregon, USA. August 16-21, 2015.

Stokes, G., Castello, L., Martins, E. G., Petersen, T., Cooke, S. J. and Zuanon, J. Habitat use and migration of arapaima in the Purus River, Amazonas, Brazil. XXI Encontro Brasileiro de Ictiologia, Recife, PE, Brazil. February 2015.

Stokes, G. L., Castello, L., Martins, E. G., Petersen, T., Cooke, S. J. and Zuanon, J. Migration, habitat use and breathing rates of Arapaima sp. in the Purus River. 3rd International Conference on Fish Telemetry, Halifax, NS, Canada. June 2015.

Teffer A.K., Bass A., Miller K., Jeffries K., Patterson D., Farrell A., Cooke S., Juanes F., Hinch S. 2015. Surviving Bycatch: multiple stressors and disease processes of Pacific salmon. Third International Conference on Fish Telemetry, Halifax, NS, July 14, 2015

Teffer A.K., Bass A., Miller K., Jeffries K., Patterson D., Farrell A., Cooke S., Juanes F., Hinch S. 2015. Surviving Bycatch: Interactions of Temperature, Stressor Severity, and Physiological Disease Processes. American Fisheries Society Annual Meeting, Portland, OR, August 18, 2015

Teffer A.K., Bass A., Cook K., Miller K., Patterson D., Farrell A., Cooke S., Juanes F., Hinch S. 2015. Stress and disease susceptibility of wild adult Pacific salmon. Salmon Ocean Ecology, Victoria, BC, March 26, 2015

Welch, DW, EL Rechisky, AD Porter, NB Furey, Scott G Hinch. 2015. Testing aquaculture impacts on wild salmon using double-blind telemetry studies. International Conference on Fish Telemetry. Halifax, Nova Scotia. July 16, 2015.

Young, N. 2015. Knowledge politics in Canada: understanding government approaches to science and knowledge in an age of uncertainty. Canadian Sociological Association meetings, Ottawa.(June 1-5 2015).

10. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

October 2014 – Martins was interviewed by FishSens Magazine on his research on entrainment vulnerability of adult bull trout through hydropower turbines (collaboration with Cooke, Michael Power, Joanna Mills Flemming and Ian Jonsen). The interview can be found on this link: http://magazine.fishsens.com/entrainment-study-tracks-bull-trout-keep-fish-canadian-dams-turbines.htm

November 2014 – Martins was interviewed by photographer and radio show host Adriano Gambarini on the telemetry project he is conducting in the Amazon to track arapaima (collaboration with Cooke and Power). The interview will be broadcast (date TBD) in the show Planeta Eldorado (Radio Eldorado, Sao Paulo) and used in a short documentary being produced by the interviewer.

February 2-15 – McLean's white sturgeon research collaboration with the US Fish and Wildlife is mentioned in their newsletter.

June 19, 2015 - McLean's collaborative work with the province of BC and the BC Sportfishing Group is featured on CBC's The National and CBC online.

August 16, 2015 – Hinch interviewed on CBC Radio, Cross-Country Checkup

September 2015 – Farrell and Hinch were interviewed by BBC for upcoming documentary series being shot in BC

December 2014 – September 2015: Farrell Interviewed byCTV, CBC Radio; CKNW Radio; Business Week Vancouver

b) Invited or contributed open-to-public presentation/contribution

Martins, E. G., D. A. Patterson, Bradford, M., Moore, J. W. and Power, M. Cumulative effects of stressors and management actions for Fraser River sockeye salmon: an introduction to the project. Open House at the Centre for Coastal Science and Management: Interconnected Problems Need Interconnected Solutions. Simon Fraser University, Burnaby, BC. October 2014.

c) Invited or contributed presentation/contribution at a workshop

Banet, A.I., Healy, S.J., Eliason, E.J. S.G. Hinch 2015. Effects of maternal stress on juvenile salmon aerobic performance. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Bass, A. 2015. Visual injury assessment from multiple projects. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Bett N.N., S.G. Hinch. 2015. Olfaction and homing: Hierarchical navigation during the salmon spawning migration. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Burnett, N.J., and S.G. Hinch. 2015. Improving wild sockeye salmon migration success through a dam management experiment. Gates Creek Sockeye Workshop: Connecting Monitoring and Management. Cheakamus Centre, Squamish, BC. March 5th, 2015.

Burnett, N.J., and S.G. Hinch. 2015. Improving wild sockeye salmon migration success through a management experiment. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Casselman, M.T. 2015. Overview of salmon migration issues and mitigation measures associated with BC Hydro operations in the Seton-Anderson Watershed. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Chapman, J.M., D.A. Patterson, K.M. Miller, S.G. Hinch, S.J. Cooke. 2015. Migration of Coho salmon released from recreational angling and gillnet fisheries. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Cook, KV. Hinch, SG, Cooke, SJ., Drenner, SM., Raby, GD, Patterson, DA., Halfyard, E. 2015. Post-release mortality in Pacific salmon captured at different points along their return migration. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Dick, M., S.G. Hinch, Cooke, S.J. 2015. Effects of tagging/handling on migrating adult sockeye salmon. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Farrell, A.P. 2015. Benefits of screening and training wild and hatchery fish, Fitsmolt workshop Oslo March 2015.

Farrell, A.P. 2015. Fishing for Answers: Cardiac physiology. Palmer Research Station, Antarctica, April 2015.

Furey, N.B. 2015. Movements of juvenile sockeye salmon migrants and predatory bull trout in freshwater. 8th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 5, 2015.

Hahn, L., Garrone-Neto, D., Nunes, L. D., Machado, L. S., Kilpp, J. and Martins, E. G. 2015. Partial migration of red-tail catfish (Phractocephalus hemiliopterus) in the Xingu River revealed by combined acoustic and radio telemetry [translated title]. I Movement Ecology Brazil Workshop. Universidade Estadual Paulista Julio de Mesquita Filho, Rio Claro, SP, Brazil. September, 2015.

Hahn, L., Martins, E. G., and Castello, L. Fish telemetry research in the Amazon. XXI Encontro Brasileiro de Ictiologia. 2015. Symposium on Telemetry and Mark-Recapture of Fishes. Recife, PE, Brazil. February 2015. Note: both Hahn and Martins presented.

Hinch, S.G. 2015. Summary of results from BRGMON-14 salmon program. Bridge River Generating Complex Water Use Planning Workshop, Lillooet, British Columbia, June 2,1015.

Martins E.G. 2015. Developing integrated population models to investigate cumulative effects on Fraser River sockeye salmon. Gates Creek Sockeye Workshop: Connecting Monitoring and Management. Cheakamus Centre, Squamish, BC. March 5th, 2015.

Martins, E. G., Patterson, D. A., Bradford, M., Moore, J. W. and Power, M. 2015. A life-cycle modeling approach to investigate cumulative effects on Fraser River sockeye salmon dynamics. Gates Creek Sockeye Workshop: Connecting Monitoring and Management. Cheakamus Centre, Squamish, BC. March 5th, 2015.

Martins, E. G., Hinch, S. G., Cooke, S. J., Miller, K. and Farrell A. P. 2015. A synthesis of salmon tracking studies in the OTN Pacific Arena. XXI Encontro Brasileiro de Ictiologia. Symposium on Telemetry and Mark-Recapture of Fishes. Recife, PE, Brazil. February 2015.

McLean, M.F., Litvak, M., Hinch, S., Cooke, S., Crossin, G. 2015. Stressed out sturgeon? Mid and Lower Fraser River White Sturgeon Community Working Group. Surrey, B.C. March 18, 2015.

McLean, M.F., Litvak, M., Hinch, S., Cooke, S., Crossin, G. 2015. Physiological and behavioural impacts of C&R angling on white sturgeon in the Fraser River, B.C. 2nd Annual OTN White Sturgeon Workshop. UBC, British Columbia. February 6, 2015.

Middleton, C.T., N.J. Burnett, D.C. Braun, E.G. Martins, V. Minke-Martin, M.T. Casselman, S.G. Hinch. 2015. Sockeye salmon migration through the Seton-Anderson hydropower system. Instream Fisheries Research, Gates Creek Sockeye Workshop: Connecting Monitoring and Management. Cheakamus Centre, Squamish, BC. March 5, 2015.

Minke-Martin, V., Middleton, C.T., Braun, D.C., Burnett, S.J., Casselman, M.T., Hinch, S.G. 2015. Migration success and thermal experience of sockeye following dam passage. Gates Creek

Sockeye Workshop: Connecting Monitoring and Management. Cheakamus Centre, Squamish, BC. March 5, 2015.

Minke-Martin, V., Middleton, C.T., Braun, D.C., Burnett, N.J., Casselman, M.T., Hinch, S.G. 2015. Migration behaviour, thermal experience, and spawning success in adult sockeye salmon. 8th annual workshop on salmon migrations, climate change, and capture/release fisheries. University of British Columbia, Vancouver, BC, February 5, 2015.

Nguyen, V.M. 2015. Science Communication Workshop Part II: Knowledge mobilization. International Conference of Fish Telemetry, Halifax, NS, July 13-17, 2015.

Raby, G.D. 2014. Methods for estimating post-release mortality in Pacific salmon. Workshop on Methods for Estimating Discard Survival II, International Council for the Exploration of the Sea (ICES) headquarters, Copenhagen, Denmark, November 25, 2014.

Raby, G.D., J.W. Brownscombe, A.J. Danylchuk, and S.J. Cooke. 2014. Post-release behavioural impairment and predation risk in tropical hook and line fisheries. Workshop on Methods for Estimating Discard Survival II, International Council for the Exploration of the Sea (ICES) headquarters, Copenhagen, Denmark, November 25, 2014.

Sopinka, N., Hinch, S., Patterson, D. 2015. Intergenerational effects of stress in sockeye salmon. 8th Annual Workshop on Salmon Migrations, Climate Chance and Capture/Release Fisheries, University of British Columbia, Vancouver, British Columbia, Canada. February 5, 2015.

d) Invited or contributed presentation/contribution at a seminar series

Bett, N.N. 2015. Animal Navigation. Presentation for visiting students from Nitobe College, Japan. University of British Columbia, Vancouver, Canada. September 12, 2015.

Cooke, S.J. 2015. Biology in a changing world – myth busting 101. Ontario Biology Day, Carleton University, Ottawa. Plenary Speaker for 200 undergrad students at Ontario-wide conference. March 2015.

Cooke, S.J. 2015. Do fish really feel pain? Cornell University, School of Veterinary Medicine, Pain Management Club, Ithaca, NY. Invited Presentation and Panel Discussion (Participated via Skype due to inclement weather). February 2015.

Cooke, S.J. 2015. Fishing for answers – context matters in catch-and-release science. Symposium on Conservation Physiology. Society for Integrative and Comparative Biology, West Palm Beach, FL. Invited Presentation. January 2015.

Cooke, S.J. 2014. Bycatch in inland waters – application of physiological and behavioural tools and concepts to address a conservation problem. Departmental Seminar, Fish, Wildlife and Conservation Biology, University of Minnesota, Minneapolis, MN. Invited Presentation. October 2014.

Cooke, S.J. 2014. The science of catching and releasing fish. Annual Kolshorn Lectureship (one annually, voted on by entire department), Fish, Wildlife and Conservation Biology program,

University of Minnesota, Minneapolis, MN. Invited Lectureship open to members of the public. October 2014.

Cooke, S.J. 2014. Conservation physiology and behaviour – fishing for solutions. National Wildlife Research Centre of Environment Canada, Invited Presentation (only non-government presenter). October 2014.

Donaldson, M.D. 2015 Context-specific responses of Pacific salmon to fisheries-related stressors. University of Ottawa Comparative Physiology Seminar Series, Ottawa, Ontario, April 15, 2015

Drenner, S.M. 2014. Homing sockeye salmon in the Strait of Georgia, BC. Department of Forest and Conservation Sciences Seminar, University of British Columbia. November 12, 2015.

Eliason, E.J. 2015. Fish Physiology: Examining how fish cope with environmental stressors. Danish Technical University. Hirtshals, Denmark. April 13, 2015.

Eliason, E.J. 2014. Climate Change: From Canada to the Bahamas. Cape Eleuthera Institute. The Bahamas. December 9, 2014.

Furey, NB, SG Hinch, AG Lotto, AL Bass, V Minke-Martin, CT Middleton, MT Casselman, TD Clark, EL Rechisky, DA Beauchamp, M Gale, K Jeffries, A Porter, DW Welch. 2015. Movement ecology of migrating juvenile sockeye salmon and binge-feeding bull trout. Seminar at the University of Massachusetts, Department of Ecology and Environmental Conservation. January 29, 2015.

Hinch, S.G. 2014. How do juvenile salmon decide to move seaward, and what are the consequences when they do: views from big and small rivers. Biology Department Seminar, Carleton University, Ottawa, ON, December 2014

Martins, E. G. 2015. Movement and entrainment risk of adult bull trout in a hydropower reservoir. Applied Ecology Seminar. Fisheries Centre, University of British Columbia, Vancouver, BC. January 23, 2015.

McLean, M.F., Litvak, M., Hinch, S., Cooke, S., Crossin, G. 2015. All Things Acidpenseridae: Physiological and behavioural impacts of C&R angling on white sturgeon in the Fraser River, B.C.U.S. Fish and Wildlife Abernathy Fish and Technology Center Seminar Series. Longview, Washington, USA. February 26, 2015.

Minke-Martin, V. Middleton, C.T., Braun, D.C., Burnett, N.J., Casselman, M.T., Hinch, S.G. 2015. Migration behaviour, thermal experience, and spawning success in adult sockeye salmon. Fisheries Centre Seminar Series, University of British Columbia, Vancouver, BC. April 10, 2015

Raby, G.D. 2014. Facing the river gauntlet: the effects of fisheries capture on the physiology and fitness of Pacific salmon. University of Ottawa Comparative Physiology Seminar Series, Ottawa, Canada, November 19, 2014.

Sopinka, N., Hinch, S., Patterson, D. 2015. Maternal stress in salmon: the science & the poetry. ARC Centre of Excellence for Coral Reef Studies Seminar Series, James Cook University, Townsville, Queensland, Australia. June 9, 2015.

Sopinka, N., Hinch, S., Patterson, D. 2014. Maternal stress in salmon: the science & the poetry. Comparative Physiology Seminar Series, University of Ottawa, Ottawa, Ontario, Canada. December 3, 2014.

Teffer, A. 2014. Effects of temperature and handling on infectious disease potential and survival of adult salmon. Department of Biology, University of Victoria. November 10, 2014

Young, N. 2015. Knowledge mobilization and fisheries science, Nofima Research Institute, Tromso, Norway, April 15, 2015

e) Awards received

Banet, A. - Best 12-minute Presentation, Pacific Ecology and Evolution Conference. February 28 2015.

Bett, N. - Best Student Paper – American Fisheries Society Washington-B.C. Annual Meeting 2015

Chapman, J. – Runner-up, Larkin Award, American Fisheries Society, 2015

Cooke, S.J. - Elected as Member of the Royal Society of Canada College of New Scholars, Artists and Scientists

Farrell, A.P. – Award of Excellence from the America Fisheries Society, 2015

Farrell, A.P. - Elected as a Fellow of the Royal Society of Canada, 2015

Furey, N. - Killam Graduate Teaching Assistant Award – Faculty of Forestry, 2015

Hinch, S.G. – Elected as a Fellow of the Society, American Fisheries Society, 2015

Jain, S. - Chancellor's medal for highest academic achievement of an undergraduate at Carleton University

Minke-Martin, V. - Awarded Cordula and Gunter Paetzold Fellowship, 2015

Minke-Martin V. - Runner-up for John E. Skinner Memorial Award, American Fisheries Society, 2015

Nguyen, V. - Skinner Memorial Award, American Fisheries Society, 2015

Nguyen, V. - J. F. Allen Scholarship Honorable Mention, American Fisheries Society, 2015

Nguyen, V. - Wyndham Scholarship for Excellence in Environmental Biology, 2015

Nguyen, V. - Peter A. Larkin Award in Fisheries Excellence, 2014

Sopinka, N. – Awarded Eugene Maughan Graduate Student Scholarship, 2014

Sopinka, N. - Member of the Year, Ottawa Field-Naturalists' Club, 2015

Sopinka, N. - Runner-up, Peter Larkin Award for Excellence in Fisheries, 2014

f) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, conference proceedings, as well as a contribution to a larger piece of work in any of the former (Note: please provide web links to the reports where possible)

Casselman, M.T., N.J. Burnett, N.N. Bett, C.T. Middleton, V. Minke-Martin, D.C. Braun, D. McCubbing, and S.G. Hinch. 2015. BRGMON-14 Effectiveness of Cayoosh flow dilution, dam operation, and fishway passage on delay and survival of upstream migration of salmon in the Seton-Anderson watershed. Annual Report – 2014. Report prepared for St'át'imc Government Services and BC Hydro. The University of British Columbia, Vancouver, BC. 67 p. + 2 Apps.

Rechisky, EL, DW Welch, AD Porter, TD Clark, MK Gale, NB Furey, SG Hinch. 2015. Telemetry-based estimates of early marine survival and residence time of juvenile Sockeye Salmon in the Strait of Georgia and discovery passage, 2014. Pages 173-179 in Chandler, PC, SA King, RI Perry (eds). State of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems in 2014. DFO Can. Tech. Rep. Fish. Aquat. Sci. 3131. Available at http://www.dfo-mpo.gc.ca/Library/358018.pdf

Raby led the writing for a 4200-word section of text on the use of electronic tagging in studies of bycatch and discard mortality. The text was contributed to a larger report (not yet published) commissioned by the International Council for the Exploration of the Sea (ICES) that will provide guidelines on methods for estimating discard mortality in commercial fisheries.

1) Data deposition to OTN Data Centre

July 2015 – Healy deposited steelhead meta-tagging data to OTN

September 2015 – Furey et al. posted Pacific salmon smolt telemetry data to the OTN Publication Data Repository to be publicly accessible. Data included are from the following publication: Furey, NB, SP Vincent, SG Hinch, and DW Welch. 2015. Variability in migration routes influences early marine survival of juvenile salmon smolts. PLoS ONE 10(10): e0139269.

September 2015 – Clark et al. posted Chilko sockeye salmon smolt telemetry data to the OTN Publication Data Repository to be publicly accessible. Data included are from the following publication: Clark, TD, NB Furey, EL Rechisky, MK Gale, KM Jeffries, AD Porter, MT Casselman, AG Lotto, DA Patterson, SJ Cooke, AP Farrell, DW Welch, and SG Hinch. Accepted. Tracking the migration of wild sockeye salmon smolts to the ocean reveals distinct regions of nocturnal movement and high mortality. Ecological Applications.

i) Invited or contributed consultations (e.g., stock assessment meetings, contributions to policy/management decisions, etc.)

March 24-25, 2015 – McLean was invited to the Centre for Science Advice Pacific's (CSAP) Regional Peer Review (RPR) meeting on white sturgeon recovery potential assessment in the lower Fraser River

to provide information on the LFR population of white sturgeon that will help form the updated RPA document for the Species at Risk Act.

April 23, 2015 – K. Cook was invited to meet with Skeena Fisheries Commission Technical Committee, Terrace, BC.

July 2015 – McLean was invited to a private meeting at the Vancouver Aquarium regarding the future of an ECHO program to protect marine cetaceans from ship noise. Her expertise on tagging and tracking of large-scale aquatic migrators was of interest to the group.

l) Internet publishing, portal, blog, electronic publications

November 2014 – Furey's research on Chilko sockeye salmon smolt telemetry is highlighted in the newsletter "Salmon Steward" published by the Pacific Salmon Foundation. Article titled "Tracking individual salmon behaviour and mortality." Authored by Mikelle Sasakamoose. Available at http://digital.canadawide.com/i/407926-winter-2014.

December 2014 – Furey's research on Chilko sockeye salmon smolt telemetry is highlighted by the University of British Columbia's Faculty of Forestry website. Available at http://www.forestry.ubc.ca/2014/12/listening-in-on-salmon-migration/.

December 24, 2014 – FishSens Magazine publishes an article on Furey's work examining bull trout consumption of outmigrant Chilko sockeye salmon smolts titled. "Bull trout found gorging on sockeye salmon smolts in British Columbia lake." Authored by Jeff Gillies. Available at http://magazine.fishsens.com/bull-trout-found-gorging-sockeye-salmon-smolts-british-columbia-lake.htm

February 2015 – Minke-Martin provided a profile on her research on adult sockeye salmon migration and spawning success for the American Fisheries Society (AFS) Ontario Chapter Student Subunit: http://www.afs-oc-subunit.org/#!Dam-passage-thermal-experience-and-spawning-success-how-are-Gates-Creek-sockeye-salmon-impacted-by-hydropower/c1cyz/22C4A234-4CD0-4A69-BC34-079F9B6378DF

February 15, 2015 - Sopinka collaborated with science communication blog Buzz Hoot Roar (www.buzzhootroar.com) and wrote an article about nest building in fishes (http://buzzhootroar.com/nest-building-its-not-just-for-the-birds/)

March 2014 to October 2015 - Sopinka writes a blog called Phish Doc (www.phishdoc.com) where she communicates concepts in fish and fisheries with haikus. Phish Doc is part of Science Borealis (http://scienceborealis.ca/), a platform featuring Canadian bloggers from a variety of scientific disciplines. Science Borealis is sponsored by Canadian Science Publishing and Genome Alberta.

August 2015 - Eliason wrote an invited blog post for the EcoEvoEvoEco blog on Eco-evolutionary dynamics titled "The Heartbreak of Salmon Migration" http://ecoevoevoeco.blogspot.ca/2015/08/the-heartbreak-of-salmon-migration.html

September 16, 2015 – Hakai Magazine published an article online titled "Fishing for a Glimpse of Salmon's Future" featuring research conducted by OTN investigators from UBC, DFO, and Carleton University who are seeking to understand how Fraser River sockeye salmon deal with temperature-induced stress and whether they will adapt to rivers warmed by climate change. http://www.hakaimagazine.com/article-short/fishing-glimpse-salmons-future

September 2015 - Sopinka collaborated with science communication blog Squidtoons (www.squidtoons.com) and contributed content and editorial feedback to a comic on the salmon life cycle (http://www.squidtoons.com/sockeye-salmon-life-cycle-from-red-eggs-to-redd-eggs.html).

m) Anything else that isn't a primary publication that has you communicating with others

Burnett, N.J. 2015. Burst and bust: understanding sockeye salmon migration mortality. UBC Forestry Branchlines 25:8-9.

Eliason (June 1-5, 2015) - an invited participant at a workshop on "The effects of global climate change on inland fish and fisheries in the United States and Canada", hosted by the U.S. Geological Survey's National Climate Change and Wildlife Science Center (NCCWSC), USGS Northern Rocky Mountain Science Center in Bozeman, Montana.

Hinch (March 2015). Presentation on Pacific salmon biology, life history and conservation to 30 primary school children at Queen Elizabeth Elementary, Vancouver, BC

Middleton, C.T. 2015. Beyond the dam: examining sockeye salmon migration through a regulated watershed. Branchlines Volume 26 #3, Winter 2015. UBC Faculty of Forestry Publication.

Minke-Martin (2014-2015) - a member of the Executive Committee of the British Columbia Student Subunit of the American Fisheries Society. The Subunit holds networking and socializing events for fisheries students in BC. The Subunit regularly updates its website and Facebook page with fisheries related news, job opportunities, scholarships and conferences.

Nguyen (2014-2015) - a member of the Executive Committee of the Ontario Student Subunit of the American Fisheries Society. The Subunit holds networking and socializing events for fisheries students in Ont. The Subunit regularly updates its website and Facebook page with fisheries related news, job opportunities, scholarships and conferences.

Nguyen (2014-2015) - the northeastern representative for the Education Section Student Subunit of the American Fisheries Society and published a series of "How-to" articles in Fisheries (student angle) for students and early career researchers.

Raby (March 2015) – publishes a short article on his research trip to Lizard Island (Queensland, Australia), which was partially funded by an OTN-HQP travel grant, in the March bulletin of the Society for Experimental Biology (pp. 33). OTN is acknowledged for their support in the article.

Sopinka (January 2014 to present) - writing articles for the American Fisheries Society's magazine, Fisheries. The articles are written in language accessible to all members of the Society. The latest article was a summary of the 3rd International Conference on Fish Telemetry. Additional articles include:

- Sopinka, N. 2015. Listening to Fishes to See Where They Go. Fisheries 40(10), 524.

- Sopinka, N. 2015. Fish and fisheries in the dark. Fisheries 40(9), 476.
- Sopinka, N. 2015. Try this! "Tweeting the Meeting." Fisheries 40(8), 428.
- Sopinka, N. 2015. Try this! Sketch Your Conference Notes. Fisheries 40(7), 338-339.
- Sopinka, N. 2015. From Your Body to Theirs: How Exposure to Pharmaceuticals Is Altering Gene Expression in Fishes. Fisheries 40(6), 292.
- Sopinka, N. 2015. Fishy Tales from Science Communicators in the Pacific Northwest. Fisheries 40(5), 240.
- Sopinka, N. 2015. Hitch-Hiking Beaver Spotted Napping Atop Humpback Whale. Fisheries 40(4), 187.
- Sopinka, N. 2015. Living Fossil Fishes, Fisheries 40(3), 140.
- Sopinka, N. 2015. Underwater Romance: A Valentine's Day Ode to Fishes. Fisheries 40(2), 84-85.
- Sopinka, N. 2015. Fishes on the Move as Oceans Heat Up. Fisheries 40(1), 32.

Sopinka (August 19, 2015) - co-organized a science communication symposium for the 145th American Fisheries Society Annual meeting which took place in Portland, Oregon. OTN members, Sopinka, Minke-Martin and Nguyen contributed oral presentations to the symposium. The symposium was featured on PLOS Blogs (http://blogs.plos.org/scicomm/2015/08/31/fisheries-science-meets-scicomm-to-tweet-or-not-to-tweet/).

n) Leveraging your research/funds in order to make a new contribution to another initiative

OTN Pacific project 4.15 was leveraged to undertake expanded related research (2015-2018). Hinch, Furey, Miller, Farrell, and Cooke were awarded $260,975 by the Salish Sea Marine Survival Project (the Pacific Salmon Foundation) to continue to examine the physiology, behaviour and survival of Fraser River salmon smolts using physiological telemetry. The OTN, through its CFI infrastructure funds, has agreed to loan 35 VR4s to this endeavor as additional leverage, and project 4.15 will provide some in-kind support via personnel and equipment. In addition, this above grant was further leveraged through the Mitacs Accelerate Program to receive an additional $102,666 to provide support for HQP.

OTN Pacific project 4.12 was leveraged to undertake expanded related research (2015) through an NSERC ENGAGE grant ($25,000) awarded to Hinch to evaluate the impairment in Chum salmon incidentally captured in commercial pink salmon fisheries in coastal management Area 6, an elaboration of project 4.12. We further received $55,000 of in-kind support from Canfisco (Canadian Fishing Company). The project was motivated by the ENGO community who had threatened to disrupt the commercial fishery if by-catch handling practices were not improved. This research project was a means of moderating this dispute and encouraging the development of better handling practices. The success of this project has motivated the ENGO community and Canfisco to encourage us to continue this type of research in a different fishing area (Management Area 3) on different species – we will be submitting another ENGAGE grant and have already applied for Pacific Salmon Commission funds for this work in 2016 (see 'spin-offs' below).

OTN Pacific projects 4.12 and 4.15 have been used to leverage funds with the Strategic Salmon Health Initiative (SSHI) led by OTN collaborator K. Miller (DFO). This program involves the development of 'salmon Fit Chips' which comprise a series of 96 quantitative PCR assays predictive of the health and condition of salmon, and the use of these Chips on biopsy tissues from telemetry tagged salmon. These are matching funds meaning the SSHI was able to secure an additional ~ 400K arising from OTN Pacific funds.

o) A spin-off from the research that provided a new opportunity or new initiative

The ENGO community, DFO management, and Canfisco have strongly encouraged us to continue with the work they financially supported in Area 6 (BC central coast) in another contentious location of the commercial purse seine fishery (BC north coast, Area 3). In order to fund this work, in September 2015, we submitted a Letter of Intent proposal to the Northern Endowment Fund of the Pacific Salmon Commission, which was recently accepted, enabling a full proposal to be written (it is due November 2015). We are asking for ~ 100K. By leveraging the final year of OTN Pacific Project 4.12, and the continued in-kind support of Canfisco, we have an excellent chance of success. We realize this is the final year of the NSERC OTN which requires 'wrapping-up' projects however this project serves three significant functions: i) it is driven by user groups, DFO, and stakeholders with direct real world application of the results to a large contentious issue with huge financial implications, ii) it represents 'bridge-funding' to help carry the Pacific Arena investigators forward past the end of OTN.1 towards OTN.2 (we can then use this bridge-funding to leverage towards a new NSERC Strategic grant to carry us well into the new OTN.2), iii) this work represents a logical final month of research for PhD student Katrina Cook in 2016.

The Salish Sea Marine Survival project funded by the Pacific Salmon Foundation has provided transmitters and personnel that can be used in a new research program that would be supported through the BC Salmon Farmer's Association. They are interested in understanding the movement patterns of Harrison River sockeye smolts which are believed to not pass by high density salmon sea pens unlike most other Fraser River sockeye smolt populations. We will be putting in a proposal to their funding envelope in Dec. 2015, leveraging both the Salish Sea project funds AND the OTN acoustic line infrastructure which we hope will still be in place in 2016-2017.

Furey supplemented his field work associated with Project 4.15 with the collection of stomach contents from bull trout feeding on outmigrant sockeye salmon smolts. These opportunistic collections have resulted in two new initiatives. First, through collaboration with the University of Washington (Dr. David Beauchamp) and the USGS (Dr. Matthew Mesa), the bioenergetics of hyperphagia (over-feeding) in bull trout is being investigated. The first publication from this initiative was published in January 2015 at the Journal of Fish Biology. The second publication from this initiative is currently in preparation. Second, through collaboration with Miller (OTN PI), the physiological condition of smolts predated on by bull trout is being compared to the general outmigrant population via novel genetic techniques to assess the role of pathogens on smolt predation.

Furey is developing a project along with other OTN HQP (Kessel, Martins, Hussey, Yurkowski) to examine the movement rates of aquatic and marine organisms across ecosystems. This research is a spin-off of the recent Science publication written by OTN HQP and PIs (Hussey et al. 2015), and uses an OTN-managed database of telemetry-related citations in the peer review literature.

Patterson (DFO, Hinch and Cooke (and their OTN HQP) are leading the developing of a document that reviews all of the science results involved with capture/release mortality in Pacific salmon that will be submitted to the Canadian Scientific Advice Secretariat (CSAS). Given the volume of science just from the Pacific OTN, DFO managers seem unable to readily incorporate findings into management actions. This advice document will codify many of the OTN findings and enable better knowledge transfer and use by DFO managers.

p) A new technology, method, protocol, measure, analytical technique, algorithm, operational or numerical model, or predictive tool. Include the validation of any of the former and their practical application

We ground truthed and tested new physiological and activity biologgers at the Cultus DFO lab. That work is directly linked to Cooke's NSERC E.W.R. Steacie Award.

q) A proof of concept in relation to any of the above

Furey developed a proof of concept individual-based model (IBM) to simulate salmon smolt migrations in the Salish Sea by incorporating ocean simulation models developed by collaborators at the University of Washington (Drs. Neil Banas and Parker MacCready) and DFO (Dr. Mike Foreman) into an ecologist-friendly format (using NetLogo software). This model is a critical first step in developing realistic simulation models of smolt movements in the marine environment to better understand migration routes, movement behaviours, and potential factors influencing migratory success.

Teffer, Bass and Cook are using novel high-throughput molecular technology (in the lab of K. Miller) paired with non-lethal repeated gill biopsy sampling and long-term holding to monitor infectious disease processes in wild adult salmon exposed to temperature and fisheries stressors. The Fluidigm Biomark qPCR platform allows us to simultaneously quantify loads of viruses, bacteria and other parasites with changes in host gene expression in gill tissue and blood properties. Such longitudinal data will contribute to a better understanding of the mechanisms associated with premature mortality of adult salmon in freshwater and disease processes in fish under optimal and stressful conditions. The techniques and tools developed for this project using the Fluidigm Biomark platform can be applied across host species and geographic regions.

r) Baseline measures (e.g. reference for change), empirical relations (e.g. rates and states), or mapping products (e.g. range expansion or contraction) especially if of use to other scientists and the organizations listed above

As part OTN Pacific projects 4.12 and 4.15, in 2015 approximately 120 smolts and 200 adult sockeye salmon were collected by OTN HQP for DFO programs to assess baseline physiological condition and stomach fullness/contents.

Over 400 tagged female Gates Creek sockeye assessed for reproductive success (0, 50, or 100% spawned) in artificial spawning channel and natural spawning creek. These data provide a reference for DFO in assessing biological impacts of tagging across years in Gates Creek and potentially across stocks.

We have collected the first Arctic char samples for disease screening using molecular tools at the Pacific Biological Station. We also have collected the first information on post release survival of Arctic char, albeit sample sizes are low (N<20) due to poor fish capture success.

Using molecular and histological tools, we have assessed the presence and relative load of 45 microbial agents potentially associated with infectious disease in wild adult sockeye, coho and Chinook salmon over three years. This broad pathogen screening provides novel and comprehensive data on the microbiome of returning adult salmon in the Fraser, identifies shared and unique microbes among species within and across years, and offers baseline information on pervasiveness and potential for pathogenicity of various infectious agents.

11. Collaborations with industrial and government partners

a) Partners

Across all Projects:

Fisheries and Oceans Canada (DFO) are involved with the day to day management of the Pacific marine fisheries and several of their scientists, biologists and technicians are directly involved with us in conducting OTN Canada Pacific research (e.g. Drs. K. Miller and D. Patterson and their lab groups). OTNC students have been training within the lab groups of these scientists. DFO genetic stock identification lab personnel (Pacific Biological Station) have been involved via processing samples for OTNC studies, and DFO Science Branch (rovided technical personnel to help in the field and lab, and have loaned equipment. DFO fisheries managers have attended our planning meetings and extension workshops in order to be updated on the latest science so that they can incorporate relevant information into on-going management plans. These managers have also been instrumental in suggesting new research opportunities, getting First Nations groups involved with our work, and helping researchers get access to fishing vessels, fishing locales, stock assessment fences, etc. in order to obtain fish for tagging purposes.

The Pacific Salmon Commission (PSC) is a US/Canada joint commission involved with the management of Pacific salmon in the Fraser River. Their staff (Mike Lapointe, Steve Latham) have attended several of our planning meetings and OTNC Canada Pacific investigators have attended some of theirs. They have provided advice and staff time in the design of our tagging experiments and have helped with stock identification through rapid scale analyses. Managers have also been instrumental in suggesting new research opportunities and helping researchers get access to fishing vessels and fish. They have helped communicate our research results to fisheries managers via their bi-annual Fraser Panel Meetings.

4.12 Pacific salmon commercial and First Nations fisheries: delayed mortality, behaviour and physiology of released bycatch in coastal waters

David Patterson (Head, Environmental Watch Program, DFO Pacific Region); study locations include coastal BC, Fraser River Watershed; species include sockeye, chum, pink, coho, Chinook, steelhead; tagging methods include radio, acoustic, biologgers, internal attachment, external attachment; our OTN research programs are fully integrated with those of the EWatch program with HQP working in the field and lab with these DFO biologists. Patterson is a primary conduit for knowledge transfer to managers and policy.

Kristi Miller (Head, Molecular Genetics Section, DFO Pacific Region); study locations include coastal BC, Fraser River Watershed; species include sockeye, chum, pink, coho, Chinook, steelhead; tagging methods include radio, acoustic, biologgers, internal attachment, external attachment; our OTN research programs are fully integrated with those of the molecular genetics program with HQP working in the field and lab with these DFO biologists. Miller is a primary conduit for knowledge transfer to managers and policy.

Greg Taylor (Marine Conservation Council); study locations include coastal BC and lower Fraser River; species include sockeye, chum, pink, coho; tagging methods include acoustic, external visual tags; Greg has been a major player in facilitating the development of our research partnership with Canfisco and is a main player in extending our results to DFO management.

Phil Young (Canadian Fishing Company); study locations include coastal BC; species include pink, chum; external visual tags; Phil provides logistic support for our research and ensures results get used by his company.

4.13 Tracking anadromous adult salmonids in Canada's three oceans to evaluate the sustainability of catch-and-release angling practices – behavioural and physiological perspectives on estuarine fisheries

David Patterson (Head, Environmental Watch Program, DFO Pacific Region); study locations include coastal BC, Fraser River Watershed; species include coho; tagging methods include radio; our OTN research programs are fully integrated with those of the EWatch program with HQP working in the field and lab with these DFO biologists. Patterson is a primary conduit for knowledge transfer to managers and policy.

Kristi Miller (Head, Molecular Genetics Section, DFO Pacific Region); study locations include coastal BC, Fraser River Watershed; species include coho, Arctic char; tagging methods include radio, our OTN research programs are fully integrated with those of the molecular genetics program with HQP working in the field and lab with these DFO biologists. Miller is a primary conduit for knowledge transfer to managers and policy.

Les Harris (DFO central and Arctic); study locations are in Cambridge Bay, NU; tagging methods included radio.

4.14 Seasonal movements and spawning migrations of white sturgeon

Erin Stoddard (Province of BC, Lead Sturgeon Biologist); study locations throughout the lower Fraser River; Erin has been a key component of our sturgeon capture and tagging operations. Our own studies are now combined with his on-going sturgeon tracking work.

Kyle Hanson (Head Physiologist, U.S. Fish and WIldlife Service Abernathy Fish Hatchery); our partnership with Kyle has allowed us to conduct controlled behavioural and physiological stress experiments with captive white sturgeon.

Troy Nelson, Sarah Schrier, and Karl English (Fraser River Sturgeon Conservation Society, British Columbia); our collaboration with the conservation society has provided us with detailed accounts of recaptures within the catch and release recreational fishery for our tagged sturgeon. The society also provides growth characteristics and location information of our fish in the form of a mark-recapture study that has been ongoing in the Lower Fraser River for 10 years. The society also allows us access to white sturgeon caught in their annual fundraiser tagging days, which has increased our sample size.

Dan Baker (Professor, Fisheries and Aquaculture Program, Vancouver Island University, BC); our partnership with Dan has allowed us access to the only white sturgeon hatchery located in an academic setting. In 2015, were able to test the impact of repeat stressors on physiology and behaviour using captive white sturgeon housed at the VIU facility.

Community Working Group and Scientific Working Group for Fraser River white sturgeon; The working groups include all stakeholders (i.e., recreational angling guides, biologists, First Nations band members, and members from non-profit conservation organizations). By collaborating with these groups we have gained access to local knowledge of white sturgeon in the Fraser River.

Marvin Rosenau (Instructor, Fish Wildlife and Recreation Program, British Columbia Institute for Technology); our collaboration with Marvin and student's from his program has allowed for increased manual tracking of our tagged fish. Marvin runs a directed studies course where his students track the overwintering sites of white sturgeon for their project and learn about tracking technologies. Those data are provided to us at the end of the project, subsequently increasing our number of days tracked. Marvin also hosts and annual white sturgeon fishing and tagging tournament where he allows us access to the captured sturgeon.

4.15 Survival and movement rates of out-migrating juvenile salmon

David Patterson (Head, Environmental Watch Program, DFO Pacific Region); study locations include coastal BC, Fraser River Watershed; species include sockeye, chum, coho, Chinook, steelhead; tagging methods include radio, acoustic, biologgers, internal attachment, external attachment; our OTN research programs are fully integrated with those of the EWatch program with HQP working in the field and lab with these DFO biologists. Patterson is a primary conduit for knowledge transfer to managers and policy.

Kristi Miller (Head, Molecular Genetics Section, DFO Pacific Region); study locations include coastal BC, Fraser River Watershed; species include sockeye, chum, coho, Chinook, steelhead; tagging methods include radio, acoustic, biologgers, internal attachment, external attachment; our OTN research programs are fully integrated with those of the molecular genetics program with HQP working in the field and lab with these DFO biologists. Miller is a primary conduit for knowledge transfer to managers and policy

Brian Riddell (Pacific Salmon Foundation); study locations include Fraser River watershed, coastal BC; species include sockeye, steelhead; tagging methods include acoustic; the PSF provides funding and extension of our research results to the scientific and management communities and the public.

b) Contributions

Name of supporting organization: **DFO Pacific Region**	**Year 6** (2015)
Cash contributions to direct costs of research	$0
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$64,900
2) Donation of equipment, software	$34,800
3) Donation of material	$8,000
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	$107,700
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Pacific Salmon Commission**	**Year 6** (2015)
Cash contributions to direct costs of research	$0
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	$28,750
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	$28,750
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Pacific Salmon Foundation**	**Year 6** (2015)
Cash contributions to direct costs of research	$260,975
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify): tags	$100,000
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	$360,975
Is this new funding (acquired during this reporting period)?	yes

Name of supporting organization: **NSERC Engage**	**Year 6** (2015)
Cash contributions to direct costs of research	$25,000
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	yes

Name of supporting organization: **Canfisco (Canadian Fishing Company)**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	$25,000
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	$25,000
Is this new funding (acquired during this reporting period)?	yes

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.16

2. Project Title: Networking, HQP Exchange and Social Science Components

3. Project Leaders: S. Iverson (Dalhousie U), S. Cooke (Carleton U), A. Fisk (U Windsor), I. Fleming (MUN), S. Hinch (UBC), S. Vagle (DFO-Arctic, U Victoria), Nathan Young (Ottawa U)

Other OTN Canada participants: all other OTN Canada PIs
Collaborators: F. Whoriskey (OTN), social science collaborators

4. Public summary of report

A continued focus of the Networking, HQP Exchange and Social Science Components project has been on increasing integration across the NSERC Network and on the sharing of research tools and program findings within and across arenas and themes. OTN Canada annual symposia bring together all Network students, PDFs, collaborators, and PIs to present projects and results, hold specialized workshops, and discuss research strategies. The successful integration of the 5th annual OTN Canada Symposium with the 3rd International Conference on Fish Telemetry (ICFT; described further in section 4.17) meant an unprecedented opportunity for HQP to engage with the international telemetry community, gain significant exposure to valuable training during associated workshops, ignite new collaborations, seek out potential future professional positions, and ultimately showcase the work of OTN and its members. All HQP in attendance were asked to prepare either an oral (see oceantrackingnetwork.org/recap-3rdicft/) or poster presentation.

The SAC also approved that a portion of this project's budget to fund the proposed social science project entitled "*Mobilizing new science for fisheries policy and management: the case of biotelemetry and Pacific salmon species in Canada.*" Funding for the social science project was received by the University of Ottawa (PI N. Young's host instituion) on September 11, 2015 (approximately one month ago), such that there is little to report at this juncture. Research instruments were designed by N. Young throughout the month of September. A population frame (a list of potential participants) was also built during this time. A request for approval from the University of Ottawa's Research Ethics Board (REB) was submitted on September 28, 2015. One HQP research assistant (M. Corriveau) is to be hired beginning November 1, 2015 pending approval from the REB to start research.

Finally, the OTN "Futures Committee" proposed the formation of a subcommittee of existing key (senior) HQP of varying expertise to synthesize OTN research into peer-reviewed publications and other outreach materials and activities. The eight members of the Integrate Describe Expand And Synthesize OTN (ideasOTN) Committee are supporting the development of new ideas for synthesis and output and ensure the execution of these projects by involving individuals from across the Network.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	E-mail	Title*	% Time in project	% Support from OTNC	Start Date (actual date HQP started with OTN)	End Date (actual or anticipated)
Marianne Corriveau	marianne.corriveau@gmail.com	RA	50	50	1 November 2015	30 April 2016
Research Topic: Involved in project design, data collection and analysis, social science project						
Marie Auger-Methe	NA	RA	50	0*	1 Aug 2014	31 Jul 2016
Research Topic: member ideasOTN						
Eduardo Martins	NA	RA	50	0*	1 Jun 2011	31 Dec 2016
Research Topic: member ideasOTN						
Melanie Beguer	NA	RA	50	0*	17 Sept 2010	30 Sept 2016
Research Topic: member ideasOTN						
Damian Lidgard	NA	RA	50	0*	1 Jan 2010	31 Dec 2016
Research Topic: member ideasOTN						
Vivian Nguyen	NA	PhD	50	0*	1 Jan 2014	31 Dec 2016
Research Topic: member ideasOTN						
Nigel Hussey	NA	RA	50	0*	1 Jan 2010	30 Jun 2016
Research Topic: member ideasOTN						
Steve Kessel	NA	RA	50	0*	1 Jan 2012	30 Jun 2016
Research Topic: member ideasOTN						
Erika Eliason	NA	PDF	50	0*	1 Jan 2011	31 Dec 2016
Research Topic: member ideasOTN						

**members of ideasOTN receive support in the form of meeting space, teleconference lines, and admin support though OTN HQ. Refer to the individual project reports for details on actual % Support from OTNC.*

b) Role, activities, and opportunities for training

Social Science Project (N. Young): Marianne Corriveau is involved in the design of research instruments, identification of potential research participants (population frame building), field interviewing, and data analysis. All activities are being done in close collaboration with the PI. Corriveau is receiving advanced training in social science research methods.

Members of the ideasOTN Committee (Marie Auger-Methe, Melanie Beguer, Erika Eliason, Nigel Hussey, Steve Kessel, Eduardo Martins, and Vivian Nguyen, with Steve Cooke, Sara Iverson and Amy Ryan as facilitators) have been tasked with taking the lead in developing (and authoring) synthesis projects/papers and activities, which are leading to improved cross-network/arena integration and preparing OTN for future development and funding opportunities.

6. Progress towards objectives/milestones

a) Overall objectives

- HQP exchanges and selected conference attendance

- Organize and lead on NSERC Network wrap-up and synthesis activities via the ideasOTN Committee
- Further integration of OTN social sciences

Social Science Project (N. Young)

The proposed research will investigate potential avenues for translating new scientific knowledge in the field of biotelemetry into real-world fisheries policy and management strategies, using Pacific salmon species in Canada as a case study. Findings from previous research conducted by N. Young suggest that interest in new scientific findings from biotelemetry is high among both regulators and stakeholders, but that significant barriers to adoption and implementation remain. Among these barriers is lingering confusion about how biotelemetry findings "fit" with existing policies, regulatory decision-making processes, and stakeholder interests. The proposed research will address this uncertainty by investigating the potential impact and integration of biotelemetry findings with existing fisheries policy and management practices. The primary tool for this research will be scenario-building, wherein key informants are invited to develop a series of policy and regulatory options in which biotelemetry plays several possible roles (peripheral, moderate, and central). Although research will be focused in the Pacific Arena, this model can be exported across the other arenas in the future and will be useful in identifying future research needs and opportunities of broad relevance to OTN as a whole (e.g., when the Networks of Centres of Excellence proposal is developed).

b) *Progress*

Given the immense importance of the Annual Symposia and specialized workshops to the advancement of OTN Canada and the cross-project, cross-arena, and partner involvement in the training of its HQP, as well as the participation of social scientists, we have continued to allocate funds toward 1) HQP exchanges and selected conference attendance, and 2) further integration of OTN findings with the social sciences nationally and internationally.

Selected HQP Conference and Research Travel

An HQP Travel Approval Committee (TAC) was formed in 2013 on the recommendation of the SAC. Details of the TAC can be found in section 4.17. Since October 2014 the TAC has processed 10 HQP travel requests to various national and international conferences, workshops and collaborative fieldwork, in addition to funding 32 (of 48) HQP to attend the annual Symposium/3rd ICFT in July 2015. Following conference attendance, HQP are required to draft a short follow-up describing their experience and its benefit to the network. A selection of these travel reports are showcased on the OTN website as "Student Profiles" in the interest of sharing information and resources gained from these experiences. The six completed (2 HQP have not yet completed their travel) travel reports are summarized below.

Vivian Nguyen travelled to Estes Park, Colorado from Oct. 5-9 to attend the Pathways 2014 conference: *integrating human dimensions into fish and wildlife management*, where she presented her research on the movement of scientific knowledge (e.g. electronic tagging outcomes) into Pacific salmon fisheries management. The goal was to generate discussion on how telemetry findings can inform fisheries management, and narrow the gap between science and action. While there she learned the importance of response rates and biases when conducting social science studies, and methodologies useful for designing future social science projects to complement some of OTN's current natural science research.

David Yurkowski travelled Sable Island, NS in January – a critical pupping and breeding period for this population of grey seals - to assist DFO (Bedford Institute of Oceanography) with their long-term population study on grey seals and retrieve satellite and VMT acoustic tags from tagged adults. Dave gained invaluable experience handling, chemically immobilizing and retrieving tags from large phocids, taking part in the capturing and handling process of ~200 kg adult females (much larger than the Arctic ringed seals he has experience with). A critical aspect of the fieldwork entailed brand re-sighting, which entails conducting weekly whole-island censuses of all branded animals from the previous 40 years to contribute to the long-term life-history data set. Overall, this experience was an extremely unique and educational opportunity.

Xavier Bordeleau traveled to Tosenfjord, Norway where he joined Dr. Jan G. Davidsen and his team (at the Norwegian University of Science and Technology) to investigate brown trout inter-individual differences in migration strategies with special attention to variation in coastal marine habitat use in the area, which complements his work on the post-spawning and over-winter migration behaviour of Atlantic salmon spawning in the Bras d'Or Lakes by addressing a similar question in a different context. While there, Xavier gained valuable field experience setting up an acoustic array for the first time. He greatly benefited from this experience and the interactions with Dr. Davidsen, other Norwegian scientists and students to help broaden his perspectives and add value to his training as a scientist.

Shiliang Shan received OTN funding to attend the 49th CMOS Congress in Whistler, BC that brought together a wide range of scientists from across Canada, the United States, and the world with a focus on topics in atmospheric and ocean sciences related to high latitudes. By presenting his research entitled "A Modelling Study of Coastal Upwelling on the Scotian Shelf" to a wide-ranging audience, he was able to raise awareness about OTN to the broader oceanographic research community. He was also able to enhance his knowledge on the major research activities across the country and including the Arctic.

Montana McLean received funding from the HQP travel fund to host a workshop at the University of Windsor on post-processing techniques for large datasets collected using fine-scale passive acoustic receiving networks (VPS, Vemco). These unique analytical techniques were developed in collaboration with Dr. Michelle Heupel and Dr. Colin Simpfendorfer at James Cook University, Queensland, Australia. The purpose of the workshop was to assist two OTN HQP with similar analyses. This type of collaboration and knowledge transfer within the network is beneficial to all, as it increases the efficiency of analyzing large datasets resulting in increased productivity/output as a network.

Nolan Bett, a PhD candidate in Dr. Scott Hinch's research lab at the University of British Columbia, received OTN funding to travel to Sapporo to spend a week with Dr. Hiroshi Ueda and his research group at Hokkaido University. While there, he travelled to Dr. Ueda's various research spaces and learned about different research methods that he plans to incorporate into his own work (i.e., setting up a PIT antenna array in a Y-maze to track the fish's movements within the maze efficiently and unobtrusively, without the need for direct observation, which can disturb the fish, or video recorders). Nolan also presented his own research on olfactory navigation in sockeye salmon to Dr. Ueda's group and other members of his department, which allowed for a two-way flow of information and contributed to establishing a trans-Pacific connection between the two research groups.

ideasOTN Committee

The OTN "Futures Committee" proposed the formation of a subcommittee of existing key RAs/PDFs/HQP of varying expertise (natural and social scientists) to help raise OTN's profile, escalate

PR, and demonstrate significant accomplishments and output, especially in Network synthesis activities by taking the lead on identifying/developing new ideas for synthesis and output and ensuring these projects are carried through. The elected co-chairs are Marie Auger-Methe (Dalhousie) and Eduardo Martins (Waterloo). While project leads from ideasOTN were identified for the various projects, other people/HQP are engaged on a project-by-project basis. Members of ideasOTN are enabling other OTN HQP to carry out their own synthesis projects by helping to gather data and acting as a conduit for finding potential project collaborators and/or experts in the type of analyses with which they require assistance. OTN has provided conference call lines, admin and financial support as required. Currently there are 14 projects either in progress or in preparation with an additional project that is on hold until spring 2016 (awaiting submission of thesis). Along with the eight members of ideasOTN, there are over 40 collaborators that include members of OTN (HQP and PIs) and others from academia and government. The following is summary of the current projects and their status:

Review 1: K. Whoriskey, E. Martins, M. Auger-Methe, L. Gutowsky, A. Godin, J. Mills-Flemming, V. Nguyen **A primer for the design and data analysis in studies using detection and sensor data from acoustic and radio telemetry**. *Methods in Ecology and Evolution*
Summary: This paper will synthesize methods for analyzing detection data and subsequently provide advice in the form of a decision tree on how and when to apply each method based on experimental design and ecological questions of interest. In addition, we will explore and discuss the potential of new methods for analyzing detection data (e.g. Gaussian Random Fields).
Status: Reviews are in progress. The intention is to begin construction of the decision tree by January 2016 with submission in March 2016.

Review 2: D. Lidgard, D. Bowen, S. Iverson, I. Jonsen **Using bioprobes to examine predator-prey interactions in a marine system**. *Methods in Ecology and Evolution*
Summary: This paper will provide a synthesis of using bioprobes to study predator-prey interactions in the marine environment. More specifically it will: 1) introduce the ecology of predator-prey interactions; 2) provide an overview of the tools available (and their effectiveness) for studying predation in the marine environment; and 3) evaluate the most effective designs for conducting bioprobe studies and subsequently interpreting results.
Status: Literature review in progress. Writing to begin February 2016 with submission July 2016.

Review 3: M. Auger-Methe, D. Lidgard, *et al.* **Animal movement and space-use in terrestrial and marine ecosystems.** *Trends in Ecology and Evolution*
Summary: This paper will unite the space-use concepts used in marine and terrestrial ecosystems, assess the differences between terrestrial and marine space-use studies and describe how concepts developed for one ecosystem can inform research in the other.
Status: Literature review in progress. First draft planned for Apr 2016 and submission in May.

Review 4: E. Simard, M. Auger-Methe, M. Beguer-Pon, C. McKinsey, P. Archambault, (F. Whoriskey?). **Review of crustacean movement studies.** *Marine Ecology Progress Series*
Summary: This paper will review the literature on crustacean movement to identify how much is already known and what techniques are used on this specific group. We will draw parallels to the movement studies done on other species groups, in part to highlight the sectors in which crustacean movement can inform movement ecology in general.
Status: Literature review in progress. First draft Dec 2015 and submission Mar 2016.

Review 5: C. Albertsen, M. Auger-Methe, J. Mills Flemming, A. Nielsen, K. Whoriskey, I. Fleming, K. Boe. **Comparing the different formulations of state-space models for animal movement.** *Methods in Ecology and Evolution*
Summary: There are multiple formulations of animal movement state-space models, many of which are written to address similar questions. Jonsen et al. (2005) and McClintock et al. (2012) proposed two distinct models to distinguish between behavioural modes. This project will implement the different models in Template Model Builder (TMB) and formally compare the efficiency of the more widely used model of Jonsen et al. (2005) with the more biologically intuitive model of McClintock et al. (2012). A deliverable of this project is to add to the "R" argosTrack package that fits movement models to data at extreme speed.
Status: CA has completed the necessary coding for the different formulations and is gathering double tag data, i.e. GPS and Argos tracks, for further analyses. First draft is expected in March 2016 with an April submission.

Review 6: M. Auger-Methe, I. Jonsen, C. M. Albersten, G. Crossin, K. Studholme, A. Derocher, J. Mills Flemming. **Tackling the challenges of fitting movement models to marine telemetry data.** *Journal TBD*
Summary: This paper will demonstrate how to use Template Model Builder (TMB) to facilitate the analysis of a variety of movement data in order to investigate animal behaviour in the marine environment, and subsequently show that TMB reduces computational time and increases the robustness of both state and parameter estimates when analyzing large datasets.
Status: MA-M has written a draft of the sections on ARGOS and GLS. First draft is due December 2015 followed by submission in February 2016.

Review 7: M. Béguer-Pon, J. Dodson, and M. Castonguay. **Tracking eels –a review of telemetry studies on eels.** *Journal TBD*
Summary: This paper reviews 72 studies published in the primary literature between 1974 and 2015, addressing various questions regarding the use of telemetry for studying the habitat use and movements of yellow and silver eels to 1) highlight which species are the most studied, at which stages, using which technology, in which type of habitat and for what specific purpose; and 2) identify knowledge gaps and future avenues for study.
Status: Literature review in progress with submission early spring 2016.

Review 8: E. Eliason, E. Martins, K. Jeffries, M. Donaldson, G. Raby, M. Drenner, A. Teffer, K. Cook, V. Minke-Martin, N. Bett, A. Bass, S. Healy, M. Casselman
PIs: K. Miller, T. Farrell, G. Crossin, S. Cooke, and S. Hinch. **Relating biosampling with movement and survival in Pacific salmon.** *Journal TBD*
Summary: This paper will provide a comprehensive synthesis of the 100+ studies, most of which are from Scott Hinch and Steve Cooke's research groups, that have examined blood physiology and in some cases gene expression in relation to migration success/survival of Pacific salmon over the last 10+ years. We will examine the parameters that have been measured, which are indicative of migration success/survival, which species are most studied, and knowledge gaps/future areas of research.
Status: Literature review in progress. First draft February 2016 with submission in May.

Review 9: S. Kessel, N. Hussey, M. Auger-Methe, S. Cooke, M. Heupel, A. Fisk**. Does the distribution of telemetry effort bias our understanding of global aquatic ecosystems?** *Ecology*
Summary: An examination of aquatic telemetry study effort determined that current global telemetry efforts are underrepresenting biota in less politically stable nations and regions - study effort by focus

nation was categorised on the Fragile States Index's 11 group political stability scale (1 as the most stable and 11 the least). We will examine the distribution of aquatic telemetry studies across global aquatic ecosystems and determine what has influenced this distribution and how we can more effectively and efficiently distribute telemetry effort in the future (e.g., increased use of satellite telemetry, improved capacity building and collaboration with local scientists in politically unstable regions).
Status: NH and SK will decide upon which parameters to be used for the analysis. Submission is anticipated in January-February 2016.

Review 10: M. McLean, S. Kessel, and M. Litvak. **A review of sturgeon telemetry studies: what have we learned and where should we go next?** *Reviews in Fish Biology and Fisheries*
Summary: This paper will provide an overview of sturgeon telemetry (radio, acoustic and satellite) to date. We will examine the techniques that have been employed, the questions that have been addressed, and what are the opportunities for future studies.
Status: Literature review in progress. First draft expected in May/June with a July submission.

Review 11: N. Furey, S. Kessel, N. Hussey, D. Yurkowski, and E. Martins. **'What Moves You' - An analysis of aquatic and marine animal movement rates across ecosystems.** *Journal TBD*
Summary: To better understand the broader limits of marine animal movement rates, this study will employ a meta-analysis of existing studies of animal movement rates and overall scale of movements of marine animals across taxa, body size, water temperature experienced, type of marine environment (estuarine, coastal, or pelagic), and whether the animal being tracked is migratory or not. In addition, this study will assess whether or not estimated movement rates are dependent on researcher methods.
Status: Literature review in progress (NF). Analyses planned May/Jun2016. First draft expected July/August.

Review 12: S. Kessel, V. Nguyen, S. Cooke, N. Hussey, A. Fisk, S. Hinch, N. Young. **Telemetry informing management case studies: success influenced by fishery value and complexity**. *Journal TBD*
Summary: We will investigate and compare the success of three attempts to use the results of OTN studies to inform fisheries management and policy: two successful case studies and one unsuccessful. We will examine characteristics of each case study to identify and understand why some of these case studies were or were not successful in influencing fisheries management and conservation. We hypothesize that it may be driven by fishery value and complexity. We will examine the Jupiter lemon shark fishery in Florida (successful), the Greenland halibut fishery (successful), and the Pacific salmon fishery in British Columbia (partially successful).
Status: Outline and scope are being defined.

Review 13: V. Nguyen, S.J. Cooke et al. **Follow up on synthesis of impact of OTN** (similar to Cooke et al. 2011 in *Fisheries Science*)
Summary: Preliminary idea to write a follow-up on the synthesis of impact of OTN as a "5 years later" perspective piece.
Status: Outline and scope are being defined.

Review 14: F. Broell, C. Taggart, D. Lidgard **Review of accelerometry.** *PlosOne*
Summary: We propose a synthesis of all acceleration data collected - and including analysis techniques, challenges in tag applications, and best practices - within the OTN (Canada wide and global) for a cross-species analysis of movement and behaviour, which could provide insights into accelerometer-derived swimming efficiency parameters within and across species and sizes. These data could help reconcile

co-evolutionary mechanisms as well as address the ecological implications of size-dependent locomotion, such as speed and energy expenditure for direct applications (e.g. migration models).
Status: On hold until Spring 2016 after submission of thesis.

Review 15: X. Bordeleau, G. Crossin, K. Boe, and M. Auger-Methe. **Review of salmon kelts.**
Summary: This review on the population dynamics of salmon kelts would be done in the context of X. Bordeleau's PhD thesis.
Status: In preparation. M. Auger-Methe has put X. Bordeleau in touch with K. Boe (I. Fleming's student). S. Kessel and D. Lidgard are looking into connecting X. Bordeleau with a population viability anlaysis expert.

Further OTN social science integration

During last year's annual meeting the SAC approved that a portion of the budget for this project go toward funding the proposed social sciences project entitled "*Mobilizing new science for fisheries policy and management: the case of biotelemetry and Pacific salmon species in Canada*" with Dr. Nathan Young as the PI. This was an excellent opportunity to continue to engage N. Young (Ottawa U) and potentially bring in other relevant social science activities to OTN. N. Young formally became an OTN Canada PI and was invited to sit on the SAC as a voting member to share his experience and provide guidance on broadening our social science connections as we move forward (i.e., engaging other researchers, aboriginal groups, other stakeholders, etc.).

Social Science Project (N. Young): As mentioned, funding was only received on September 11, 2015, after some delays at Dalhousie University. Progress to date has included design of research instruments, population building, and the submission of an application to the University of Ottawa's Research Ethics Board on September 28, 2015.

OTN sponsored (spearheaded by David Vanderzwaag, Dalhousie University) the *American Eel Symposium: Future Directions for Science, Law and Policy* (23-25 October 2015, Portland) that served to provide an informed discussion among the scientific, legal, commercial, social and policy communities in the US and Canada on the conservation status and the key knowledge gaps relating to science management and conservation of the American eel. As a result of this meeting early discussions have commenced for joint efforts between Canada and the US to complete an integrated eel assessment, which could provide a significant conservation advantage and possibly accelerate formal cooperative arrangements.

D. VanderZwaag continues to work on Australian connections and co-hosted a meeting at the Institute of Marine and Antarctic Research in Hobart, Tasmania, to compare Canadian and Australian approaches to endangered species management, and to consider how the use of telemetry can be integrated to help generate positive outcomes.

c) Significant deviations

None.

d) Coordination and integration

Social Science Project (N. Young)

Co-Investigators Scott Hinch and Steven Cooke have participated in the design of the interview schedule, population building, and advising regarding logistics for the field research. Their expertise in biotelemetry has contributed directly to the scenario-building questions and activities at the core of the interview schedule.

e) Scientific and/or engineering significance

No results to date on the social science component.

f) Significance of research to the community/public

The output from the ideasOTN Committee will help to inform policy and management, and depending on the materials generated, will help to educate and engage the public on ocean sciences and telemetry studies both nationally and internationally.

7. Difficulties encountered

☒ Other (specify): Lengthy delay in the transfer of funds from Dalhousie University to the University of Ottawa

The delay was institutional, and had nothing to do with myself or OTN Canada. Sara Iverson, Amy Ryan, and myself wrote many emails to prod Dalhousie into action on this file.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

3rd International Conference on Fish Telemetry:

The majority of the Networking, HQP exchange, and social science component project leaders, OTN PIs, and collaborators attended the fully integrated 3rd ICFT/5th annual OTN Canada Symposium (described further in 4.17) in Halifax (13-17 July 2015) and participated in the multitude of networking activities spread out over the week, including various workshops, meetings, and social events. Several specialized workshops facilitated introductions to, or built on previous knowledge of, modeling and data analysis, acoustic telemetry design and application, and science communication. Additional workshops formally brought together groups of researchers conducting telemetry studies both in Europe (i.e., the European Aquatic Animal Telemetry Network, EAATN, hosted its first meeting under the AtlantOS Horizon2020 project) and Brazil (Tropical Fish Telemetry workshop). Two poster sessions (described in 4.17) facilitated networking and interaction among delegates including a special networking event that paired senior scientists and students/early career researchers to offer mentorship. Network integration and collaboration was further enhanced as ICFT presenters were invited to contribute to a special edition of *Environmental Biology of Fishes* that will contain presentations from the conference.

ideasOTN:

Since its formation in May 2015 and an initial meeting in June 2015, the ideasOTN Committee has met monthly (and will continue to do so) via teleconference (local members meet at OTN HQ) to discuss and develop new ideas for syntheses and ensure that these get carried through by involving members from

across the network. The existing projects (section 6b) involve a variety of OTN members including MSc and PhD students, post-docs/research associates, and PIs across five universities (e.g., Dalhousie, Carleton, Windsor, Waterloo, British Columbia).

Social Science Project (N. Young): No activities to date

b) *Interaction/Outreach to Broader Community*

Social Science Project (N. Young): No activities to date

D. VanderZwaag (OTN/Dalhousie University), working with Australian colleagues Julia Jabour and Tim Stephens, hosted a meeting (February 2015) at the Institute of Marine and Antarctic Research in Hobart, Tasmania, to compare Canadian and Australian approaches to endangered species management, and to consider how the use of telemetry can be integrated to help generate positive outcomes. The meeting was held under the aegis of ACORN, the Australia-Canada Ocean Research Network. Other Canadian OTN participants presenting at the meeting included OTN executive director Fred Whoriskey, Katie Sykes (Thompson Rivers University), and Philip Saunders, Richard Apostle and Tsafrir Gazit (Dalhousie University). The meeting was coordinated with high-profile celebrations of Canada-Australia links in polar activities hosted by Acting Canadian High Commissioner to Australia, David McKinnon.

11. Collaborations with industrial and government partners

a) *Partners*

Social Science Project (N. Young): This research is partnered with DFO-Pacific. Key point of contact is Jennifer Nener, Area Director for the Pacific Region. Ms. Nener is assisting us with access to DFO personnel with expertise in fisheries management, particularly fisheries managers. These are key participants in the research, as well as a target audience for findings.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 6 Review: 1 October 2014 – 30 September 2015

1. Project Number: 4.17

2. Project Title: Ocean Tracking Network Canada Secretariat

3. Project Leaders: S. Iverson (Scientific Director), Nikki Beachamp (Sr. Communications Manager), Amy Ryan (Network Program Officer)

4. Staff

Name	Title	% Time in project	% Support from OTNC	Start Date (actual date started with OTN)	End Date (actual or anticipated)
Sara Iverson	Scientific Director	80	0	01 Jan 2010	31 Mar 2017
Amy Ryan	Network Program Officer	100	100	01 Oct 2014	31 Mar 2017
Nikki Beauchamp	Senior Communications Manager	100	100	01 Jun 2012	31 Mar 2017
Tracy Rounds	OTN Administrative Assistant	50	0	01 Jan 2010	31 Mar 2017
Kes Morton	OTN Senior Project Manager	25	0	01 Jun 2012	31 Mar 2017
Mabel Weng	2015 Summer Co-op	100	0	01 May 2015	26 Aug 2015

5. Progress towards objectives/milestones

a) Overall objectives

The main objectives of the Secretariat in Year 6 are as follows:

i) Office operation and human resources

- Participate in regular NSERC Network and OTN Global management and advisory meetings
- Conduct daily office duties and equip the office

ii) Finances and budget re-allocation

- Oversee financial management of the NSERC Network
- Oversee reprofiling of projects and budgets as necessary
- Oversee and produce annual consolidated budget report to NSERC and the Scientific Advisory Committee (SAC) (NSERC Form 300 to be provided by Dalhousie Financial Services)

iii) Committees, meetings, symposia, workshops, and outreach

- Organize and host the 3rd International Conference on Fish Telemetry (ICFT)/5th OTN Canada Symposium
- Organize Annual SAC and Arena Leaders meetings/conference calls
- Organize regular (monthly to bi-monthly) OTN Futures Committee meetings

- Participate in regular ideasOTN meetings
- Promote understanding of role of the Network and facilitate lateral communication among HQP
- Perform general outreach, communication, and promotion of the Network

iv) Reports and proposals

- Produce a consolidated annual progress report for all projects active in 2014-2015
- Produce a promotional, public annual report on for the integrated OTN - both Canadian and international components - to distribute to current and future partners, stakeholders, industry, government, and the general public

v) Website and newsletter

- Update and maintain the OTN website
- Produce a bi-monthly newsletter to be distributed to OTN, stakeholders, management, and the broader international community

vi) Data management

- Meet regularly with OTN global data management team to discuss data policy, requirements, metadata, etc.
- Communicate above to PIs and HQP when appropriate

vii) Communication with OTN global and funding partners

- Meet regularly with OTN CFI management personnel to coordinate efforts for all of OTN

b) Progress

The Secretariat has followed up on all the main objectives and made good progress on meeting the milestones for the sixth year, as further described below.

i) Office operation and human resources

Sara Iverson is the Scientific Director for the OTN Canada Network and spearheaded the development of the NSERC proposal, as well as oversees the execution of its research program and the Network as a whole. She oversees reports to both NSERC and the SAC and manages the overall budget. S. Iverson is also the Scientific Director of OTN as a whole (both Canadian and international activities) and as such works very closely with the Executive Director (F. Whoriskey) to direct the programs of both NSERC and CFI. As Scientific Director of OTN, S. Iverson serves on the following committees:

Dalhousie committees:

- the OTN Secretariat - comprised of the OTN Scientific and Executive Directors (S. Iverson and F. Whoriskey), the Senior project Manager (K. Morton), the OTN Canada Network Program Officer (A. Ryan), the Senior Communications Manager (N. Beauchamp), and the OTN Administrative Assistant (T. Rounds), which meets bi-weekly to monthly, to strategize on overall planning of OTN activities, new initiatives, funding opportunities, and outreach;

- the OTN Status Committee - comprising all members of the OTN secretariat, the OTN data team, and the OTN technical support and glider group, which meets bi-weekly to review status and operations of OTN;

- the OTN Glider Operations Committee - which meets bi-weekly to review status, operations, issues and deployment strategies for OTN's fleet of gliders;

- the OTN Management Committee - composed of the directors of Dalhousie Research and Financial Services, Faculty of Science and OTN directors and managers, which meets twice yearly, to ensure that the OTN (Global and Canada), and the projects undertaken within its umbrella, are managed responsibly, and in accordance with CFI and NSERC guidelines and Dalhousie University regulations and policy; S. Iverson updates this committee on progress and scientific activities within both the OTN Canada Network and the international OTN community;

National/International committees:

- the OTN Canada Scientific Advisory Committee (SAC) - which meets once yearly in person (and other times as necessary by teleconference or by email) and advises and reports on the planning and coordination among all projects undertaken under the OTN umbrella in Canada;

- the OTN International Scientific Advisory Committee (ISAC) - which meets once yearly in person (and other times as necessary by teleconference or by email) and advises, reports, and helps guide the planning and coordination among scientific projects undertaken that are supported by the OTN and assists OTN in international outreach and exchange;

- the OTN Deployment Committee - a committee of three people plus invited experts, which evaluates deployment requests for OTN lines worldwide and makes recommendations to OTN Council; and

- the OTN Council - which meets once yearly in person and twice more via teleconference, and is the stewardship body for all of OTN (CFI and NSERC positions) on behalf of Dalhousie University and other stakeholders including CFI and NSERC; S. Iverson presents to Council an overview of all OTN scientific activities, strategies and plans; the Council provides direction to the scientific and management affairs of the OTN that will ensure its development and enhance the value of its research leadership and assure its financial and scientific management;

- the OTN Futures Committee - which meets monthly to bi-monthly via teleconference to discuss/define the big questions and vision for OTN with regards to science, policy and management, make recommendations on disbursements of remaining funding, and to generate idease to raise the OTN profile; and

- the ideasOTN Committee (described in 4.16) - which meets monthly via teleconference to identify ideas/opportunities for synthesis including, but not limited to, primary publications, technical papers, meta-analyses, thought pieces, or op-eds.

S. Iverson also serves as "ambassador" for OTN (in a 'tag team' with F. Whoriskey) for all local, national and international events and meetings related to oceans issues, initiatives and networks (see *iii)*, and sections 7 and 8).

Nikki Beauchamp is the Senior Communications Officer for all OTN. Reporting directly to the Scientific and Executive Directors, N. Beauchamp manages all public relations and communications activities including, coordinating international partner media releases and funding agency announcements to maximize OTN exposure. She also manages website and social media content; newsletter and public annual report production as well as strategic engagement opportunities as they arise. Working with senior staff and OTN Council, N. Beauchamp leads the development of the Communications Plan for OTN and oversees the OTN Canada HQP travel fund proposals, meetings, and approvals, as well as completed reports by HQP. She also helps prepare material for Network members for outreach activities, attends all key management committee meetings, and assists with meeting/conference organization, NSERC annual report assembly, network communication, and fund raising.

Amy Ryan is the OTN Canada Network Program Officer. Reporting directly to the Scientific Director, the A. Ryan helps to ensure the efficient management of the NSERC Network, its integration with the global network, and completion of the Secretariat's tasks that include the following responsibilities: serves as a point of contact for all other OTN Canada network members; responsible for reviewing, editing, and the assembly of the annual scientific progress and financial reports; arranging logistics, agendas, and documentation for the OTN Canada SAC, Reprofiling, and various other committee meetings; assists the Scientific Director to manage budgets and disbursement of funds to partner institutions for individual projects, for approved HQP travel, and for workshops, symposia, advisory and peer review meetings. Additionally, A. Ryan serves on all key OTN committees and interfaces with K. Morton on CFI management issues.

Tracy Rounds is the Administrative Assistant for OTN (Dalhousie-funded). In conjunction with the integration of the administration of OTN Canada and OTN Global, and the extensive communications duties required of N. Beauchamp, T. Rounds provides administrative services for OTN Canada, including helping to assemble all Network documents, organizing meetings, and taking minutes at all administrative, SAC, and Arena Leaders meetings.

Kes Morton is the OTN Senior Project Manager (CFI-funded) who is responsible for managing the CFI portion of OTN and overseeing general management and deployment of research infrastructure. In conjunction with the integration of OTN Canada and OTN Global, K. Morton works with the NSERC-funded staff to ensure coordination of OTN operations and attends and helps to plan and attend all key management committee and outreach meetings.

Mabel Weng interned with OTN (May - August 2015) as part of her Bachelor of Public Relations program at Mount Saint Vincent University. She worked with N. Beauchamp assisting with the execution of the 3rd ICFT. During her term, M. Wang created a mobile app that hosted the program and other relevant information pertaining to the conference.

Office setup. The OTN Canada Secretariat is located in the Steele Ocean Sciences Building (SOSB). This space accommodates all OTN Headquarters personnel, including administrative, data management, and field operations teams and allows for greater formal collaboration and internal cohesion, as well as casual interaction. This space also features a dedicated meeting room with audio/visual and teleconferencing abilities, a technical workspace for the field operations team, and "hot desks" for co-op students and volunteers. Also in the building are offices for the Institute for Oceans Research Enterprise (IORE; formerly the Halifax Marine Research Institute), the Marine Environmental Observation Prediction And Response (MEOPAR) NCE, and the Marine Observations Support Team (MOST),

which provides ocean glider technical and field support to OTN. Thus, the SOSB also allows for greater interaction among these large oceans-focused networks. All groups have access to a conference room for larger meetings and an atrium space for receptions and social events.

In addition to her office space in the SOSB, Scientific Director S. Iverson also retains her office as a professor within the Department of Biology in the Dalhousie Life Sciences Centre.

ii) Finances and budget re-allocation

Reprofiling. This sub-committee comprises a core of three members (currently A. Fisk (chair), Tetjana Ross, and S. Hinch) to be supplemented with additional specific expertise as needed. If one of the three members of this committee is the requester, NSERC has approved that S. Iverson serves as their replacement on the committee for that request. The committee is called to meet only as issues and needs arise. The committee reviews requests, make recommendations, and reports to S. Iverson, who then reports to the SAC and NSERC. In this manner due process should be carried out in fairly making any such decisions.

Three requests were made to the Reprofiling Committee in 2015:

1. PI Aaron Fisk requested that the equipment used for the OTN Arctic project in Resolute Bay being pulled July 2015 be re-deployed to ongoing OTN projects in the Arctic and new bi-national projects in the Great Lakes. The Reprofiling Committee approved Aaron's request to redeploy in the Arctic, as this fit nicely within the framework of the original NSERC proposal. However, it suggested that his request to redeploy in the Great Lakes be presented instead to the OTN-CFI team as an equipment loan agreement.

2. PI Chris Taggart requested that, because his current PhD student Franziska Broell is planning to defend by December 2015, the $21K currently in place for a PhD student salary in 2016 be revised to fund a her on a 6 month post-doctoral fellow stipend (January until June 2016) to undertake Year 7 wrap-up and synthesis activities. Approval by the Reprofiling Committee was unanimous, particularly due to the fact that F. Broell has been a great asset to the OTN community and C. Taggart emphasized that the funding, and Fran's continuation with the Network, will be critical for both the Halibut (OTN/NOAA/U Alaska) and the grey seal (Project 4.7) work.

3. PI Julian Dodson requested to use $3K in carryover from his 2015 OTN fieldwork budget to cover a portion of the costs associated with publishing his satellite tag observations in the journal *Nature Communications*. The total page charges were approximately $8K, but J. Dodson was able to obtain $5K ($2.5K each from Laval University and DFO, IML) in matching funds to cover part of the costs. Approval by the Reprofiling Committee was unanimous, as this is consistent with OTN profile-raising activities and recognition of excellence. The publication received significant international exposure for the Network.

HQP Travel Approval Committee. Organized on the recommendation of the SAC during the 2013 meeting, this subcommittee is comprised of OTN Canada PIs Glenn Crossin, Scott Hinch, Matt Litvak, and Svein Vagle, with N. Beauchamp as liaison. This committee reviews and approves or rejects HQP travel applications up to $1.5K. Exceptions may be made to this figure with the endorsement of PIs. Details of HQP travel are further described under Project 4.16.

iii) Committees, meetings, symposia, workshops, and outreach

The following describes meetings and workshops mostly within OTN Canada, those extending beyond the NSERC Network and other outreach and promotion of the Network are described in section 7.

Futures Committee meetings. On the advice of the OTN Scientific Advisory Committee (SAC) at the 2014 annual meeting, the OTN Futures Committee (FC) was formed to focus on wrapping up the first major phase of OTN (I & II, 2010-2016) and on finding and securing new funding opportunities for OTN's next phase (2017 and beyond). More specifically, the FC is charged with: 1) defining what the big questions and vision are with regards to science, policy and management; 2) deciding what to do with remaining funding; and 3) generating ideas for publicity related to the synthesis of data, future funding and pushing knowledge into management. The FC held it's first meeting in Vancouver (February 2015) and has since met three times via teleconference on a bi-monthly basis, and once face-to-face during the 3rd ICFT (July 2015).

3rd International Conference on Fish Telemetry (ICFT) 2015. Led by co-chairs N. Beauchamp and K. Morton, OTN organized and hosted researchers for the 3rd ICFT. The conference brought together over 250 researchers and students from 25 countries, presenting the latest in aquatic animal monitoring and conservation research from around the world. Presentations and talks included themes ranging from behavioral ecology to technological advancements in telemetry. Four distinguished plenary speakers - Rory McAuley (Australia), Chris Holbrook (USA), S. Iverson (Canada), and Francisco Chavez (USA) – offered important insight into aquatic telemetry science. S. Iverson gave a plenary on the benefit of networks to telemetry science ("The Potential of Networking to Transform Aquatic Animal Telemetry Science"). Conference workshops deepened participants' knowledge of various technologies and scientific techniques, and brought together groups of researchers conducting tracking studies. New projects were formed at the conference, including an international collaborative tracking study for the sub-Antarctic Kerguelen Islands and further development of a European Aquatic Animal Telemetry Network and OTN-Brazil.

The 5th annual OTN Canada Symposium was held in conjunction with the ICFT. This meant an unprecedented opportunity for Network members, particularly HQP, to gain significant exposure to the international telemetry community and training during associated workshops. With 32 out of the 48 current HQP and over half of the OTN Canada PIs in attendance, the ICFT offered a tremendous opportunity to showcase the work of OTN and its members. All HQP in attendance were asked to prepare either an oral or poster presentation. Two poster sessions facilitated networking and interaction among delegates. A student-only poster session was held the Sunday before the opening reception and offered students a chance to showcase their work to the broader delegation. A second poster session on Tuesday evening featured both student and non-student posters, as well as a special networking event that paired senior scientists and students/early career researchers to offer mentorship, career and project advice, and swap stories.

The ICFT was officially opened with welcoming talks from Gilles Patry, President of CFI, and Martha Crago, VPR Dalhousie. The week was packed with governance side meetings: the OTN ISAC, Council, International Data Management Committee (IDMC), and Futures Committee all held their respective annual meetings while in Halifax. Additionally, an "OTN Futures Meeting" kicked off the week to gain valuable insight from members of the broader aquatic telemetry community on the best way forward for the Network as OTN begins to prepare for the next phase and future opportunities.

SAC meetings. As a follow-up to the 2014 annual face-to-face SAC meeting in Halifax in December 2014, the SAC held a meeting by teleconference in February 2015 to receive and approve amended annual scientific and budget reports for 2014 and budgets for 2015. A second teleconference was held in June 2015 to continue to engage the SAC in discussions of the future of OTN. More specifically, the teleconference aimed to get the SAC's input on "futures activities" to date, and plans going forward, in terms of preparation for future funding and the next phase of OTN.

The 2015 annual face-to-face SAC Meeting is scheduled for 7-8 December in Halifax. The main objectives of this meeting are to review research progress of the Network, to approve Year 6 (2015) reports and budgets and review and approve proposed activities and budgets for Year 7 (2016), as well as to discuss Phase II wrap up and future funding opportunities.

2015 Ichthyology Conference (Brazil). F. Whoriskey and S. Iverson presented at the 21st Brazilian Ichthyology Conference in Recife. This was followed by a practical workshop on the use of acoustic telemetry lead by Stephanie Smedbol of VEMCO.

MEOPAR Mobilizing Science Knowledge and Research (KMB) Symposium 2015. The three-day symposium in Halifax was a KMB training and education initiative for NCEs (National Centres of Excellence) that explored moving new research into policy and management. N. Beauchamp presented a case study of OTN knowledge mobilization efforts and highlighted contributions including the 2014 OTN-hosted Parliamentary Reception in Ottawa, the ocean-themed issue of *SciencePages*, and the NSERC Kiosk event in Ottawa.

Sixth annual OTN Symposium 2016. Planning is underway by the OTN Secretariat for the 6th Annual OTN Symposium. A. Ryan is conducting a cost-benefit analysis to determine the ideal location to host the symposium. OTN is currently considering Halifax, Ottawa, and Vancouver. OTN will actively seek means for supplemental funding from industry and other partners in order to continue to make this symposium better linked between Canadian and international OTN partners. Also, we will look at holding the annual ISAC meeting in conjunction with this symposium to best leverage the travel funding provided by CFI for ISAC members and continue the excellent engagement that continues to take place between ISAC and OTN Canada PIs and HQP.

iv) Reports and Proposals

The annual progress report template was updated and distributed to PIs as a form to be completed by early November. Additions were made to the template to help make it easier to tease out and report on the items that help raise the profile of OTN and its members (i.e., awards received, information on what HQP/alumni are doing, information for the public annual report, and more detail on networking, outreach, and collaborations). Based on feedback from the SAC at the 2012 annual meeting, word limits continue to be placed on some sections and page limits on the overall project reports to reduce the volume of the combined annual report.

The approach to the financial reporting was the same as previous years. PI expenditures are matched with the NSERC Form 300s from all institutions for January - September 2015, in an attempt 1) to make budget reporting more transparent/easier for the SAC to evaluate and 2) to determine project carryovers and to help with budget request shortfalls from year to year.

The Secretariat made extensive efforts to consolidate and format the reports submitted, seek corrections and additional information where necessary, produce network summaries, and to correct and assemble complete budget reports. These are being submitted to the SAC for approval at the December meeting.

The 2015 integrated OTN Global and OTN Canada public annual report of noteworthy activities will be released early in the new year. All public annual reports are hosted on the OTN website, including the 2013-2014 released in the summer (oceantrackingnetwork.org/wp-content/uploads/2015/08/otnar_web.pdf). Hard copies are distributed during promotional events and to visiting delegations.

v) Website and newsletter

A. Ryan and T. Rounds are continuing work on building a searchable library of OTN Canada/Global publications using Mendeley that will be hosted on the OTN website. T. Rounds has updated the database of acoustic, satellite, and radio telemetry literature used for the ISAC co-authored *Science* paper to the end of October 2015. A. Ryan will gather the subset of papers from this database authored by OTN researchers to create the OTN library.

The OTN newsletter reflects the work and success of both national and international Network efforts and their increasing integration, and serves to keep OTN members, collaborators, granting councils, government and industry sponsors, and relevant members of the Dalhousie community abreast of OTN news. The newsletter has evolved to feature regular segments including global deployments and tagging projects, data, and technology updates as well as conference dates, calls for proposals, and student profiles. In fall 2014, the format and schedule for newsletter production and distribution was revised towards increasing visibility and timeliness of news reporting and now appears on a more frequent basis in a shorter, more digestible, bi-monthly format. This and various website revisions has replaced the need for an NSERC-specific news bulletin. All newsletters are hosted on the OTN website with a link sent via email to over 800 national and international partners. This recipient list continues to grow as industry, science, and media contacts are made.

In anticipation of the ICFT, a monthly newsblast was issued to keep registered and potential delegates abreast of ICFT developments. The focus ranged from news on conference and workshop registration fees and reminders, to annoucements including social events, plenary speakers, workshops, and sponsorshop. Recipients were attendees of past ICFT conferences, OTN delegates, and research and industry partners.

The OTN website was restructured in 2014 to reflect the evolving sophistocation of the Network and growing research initiatives and international partnerships. The content management system was also moved from the relatively outdated Plone (the original CMS used by the data management team) to Wordpress, a widely-used blogging platform (now accounting for 25 percent of all websites) that allows for greater manipulation of overall design/theme, content manipulation, features, and social sharing. The new website interface features a landing page comprised of network updates (posts) under categories such as ‘tagging and tracking,’ ‘latest news,’ and ‘field ops,’ with top stories featured on an eye-catching slider. The site also features a ‘Fresh off the press’ and ‘Links and announcements’ sidebar, with links to the current month’s media hits and Network annoucements (job postings, conference dates, resource links), respectively. Continuous monitoring of the analytics indicates a strong preference for a more readily accessible explanation of the Network’s overall concept and core activities—for this reason, a moderate redesign of the website is planned for 2016 to feature a static landing page with OTN’s

mission, value, objectives, and concept clearly stated. A shift in the design will be scored against the current analytics to improve user experience and boost digital engagement.

In August, OTN added another social media platform to its repertoire of digital channels: a Facebook page serves more rounded news from the Network and includes links to partners' research and non-telemetry, marine-related news. This is unlike the Twitter page, which almost exclusively puts out, "tweets", news related to OTN activities. Facebook outranks Twitter in overall traffic and branded content, while Twitter hosts more influencers and has a significantly larger share of the mobile user market while catering to a younger demographic. Both platforms serve different objectives of communications activities and broaden OTN's digital share of voice with different audiences. Views have been growing steadily on the OTN Facebook page. Additionally, the interoperability of twitter and Facebook increases productivity of social media outputs.

vi) Data management

A. Ryan meets regularly with the OTN Data Centre (OTNDC) team (Lenore Bajona, Marta Mihoff, Jon Pye, and Brian Jones) to stay apprised of the team's activities/achievements and discuss data issues. Efforts continue to ensure that PIs and HQP submit their data to OTNDC in a timely manner. A. Ryan also works with the data team to communicate requirements to PIs/HQP and assists in linking PIs to projects.

Notably, in 2015 the OTN database reached 100 million detection records! OTN also became an Associate Data Unit (ADU) of the International Oceanographic Data and Information Exchange (IODE), a programme of UNESCO's Intergovernmental Oceanographic Commission (IOC). As one of only 11 ADUs worldwide (and the only one in Canada), OTN is recognized as having established a data system built on high standards and best practices. OTN will be actively engaged in future discussions on global data-sharing.

The International Data Management Committee (IDMC) formed in July 2014 includes Kes Morton, Hassan Moustahfid (Integrated Ocean Observing System, U.S.), Fred Whoriskey, Tim Stone (Vemco, Canada), Francisco Hernandez (IDMC chair; Flanders Marine Institute Platform for Marine Research, Belgium), Jon Burgess (IMOS, Australia), Lenore Bajona (OTN director of data management), Tania Pinnell (Department of Fisheries, Western Australia), and Joanna Mills-Flemming (Dalhousie University, Canada). In 2015 the IDMC welcomed three new members, Ariel Troisi (Argentina), Taryn Murray (South Africa), and Peter Walsh (Australia). The IDMC works to:

- Oversee the OTN Data PlanDesign policies, internationally standardized procedures and data quality assurance activities at all levels for staff to implement
- Provide direction on the format, and assist with the development, of the OTN Data Warehouse
- Help identify new opportunities for data synergy among the partners
- Collaborate with Network researchers in the development of new analytical and data visualization tools

The Institute for Ocean Research Enterprise (IORE, Halifax, NS) and the Brazil-based Foundation for Research Support of the State of Rio Grande do Sul (FABERGS) teamed up and requested research proposals in the field of ocean science and technology. The OTN put forward a successful proposal in collaboration with Jose Henrique Muelbert, a researcher at the Federal University Foundation of Rio

Grande to build the OTN-Brazil data node. In November/December 2015 L. Bajona will travel to Brazil to assist in establishing this node.

This year, the data team supported the development of an acoustic telemetry network in the Gulf of Mexico, the Integrated Tracking of Aquatic Animals in the Gulf of Mexico (iTAG). Progress also continues on bringing the approximately 800 European researchers currently working in marine telemetry together into a European Aquatic Animal Telemetry Network (EAATN) through the Horizon 2020 AtlantOS program. The first EAATN meeting was held during the 3rd ICFT.

vii) Communication with OTN Global and funding partners

OTN NSERC and CFI personnel communicate regularly and collaborate on joint efforts including data management, web pages, organization of meetings, establishing a plan of projects, technician requirements, etc. S. Iverson, N. Beauchamp, and A. Ryan participated in regular Secretariat, Status, OTN Council, and ISAC meetings.

S. Iverson continues to be in contact with NSERC in terms of Network issues and deadlines, with CFI on all issues of OTN and its development, as well as financial issues, and with DFO in terms of partnering of funding. N. Beauchamp maintains communication with other funding partners, which resulted in significant sponsorship of this year's annual symposium/3rd ICFT.

c) Significant deviations

No significant deviations were experienced this year.

d) Coordination and integration

See overall network report.

6. Difficulties encountered

☒ No problems occurred during the reporting period

7. Networking and outreach

The Secretariat has continually provided ideas, extensive organizational support, and assistance in facilitation of networking, integration, and outreach to the Network. Some of the examples are given below, while more details can be found in the elsewhere in this report. The Secretariat has also been very active in communicating and promoting aspects of the Network externally.

a) Intra-network collaboration and partner meetings

N. Beauchamp and A. Ryan travelled to BC for the first meeting of the OTN Futures Committee, which was held at UBC to discuss the future of OTN (vision, NCE, etc.). While there, they attended the annual Pacific arena workshops:

- *8th Annual Workshop on Salmon Migrations, Climate Change, and Catch and Release Fisheries.* The annual event, hosted by the Pacific Salmon Ecology and Conservation Laboratory at the

University of British Columbia, brings together researchers working on Pacific salmon to engage with local stakeholders, government agencies, and first nations to communicate results, identify gaps in current knowledge, and maintain knowledge transfer between the groups.

- *2nd annual Fraser River White Sturgeon Workshop.* The workshop gathered people and groups working on white sturgeon in the Fraser River, and discussed acoustic telemetry tracking studies initiated during this past year by OTN researchers Glenn Crossin, Scott Hinch, Steve Cooke, Matt Litvak and Montana McLean.

OTN organized a "Big Ideas" contest open to all Network members in the hopes of garnering interest for the "OTN Futures Meeting" that kicked off the 3rd ICFT, and to assemble ideas for synthesis types of projects or papers and ideas for the future OTN. Network members were challenged to come up with ideas that were interdisciplinary, transformative, disruptive, and game changing, and ultimately the next "Big idea." Several Network members (including HQP, PIs and OTN HQ) submitted their ideas and two winners (Nathan Furey and K. Morton) were selected to present during the meeting on the Sunday afternoon before the conference started and were awarded a prize. Members of ideasOTN will ensure that the project ideas not selected for awards are still carried out.

T. Rounds travelled to Cape Breton providing clerical support to OTN Canada PI Bruce Hatcher. The purpose of the trip was to coordinate with B. Hatcher on the transcription of metadata for his recievers so that the data could be loaded into the OTN database.

A. Ryan serves on the ideasOTN Committee, offering administrative/logistical support and acts as liaison between the committee and the OTN Secretariat. The committee (Marie Auger-Methe, Eduardo Martins, Damian Lidgard, Vivian Nguyen, Steve Kessel, Nigel Hussey, and Erika Eliason) meets monthly to remain updated on the synthesis projects currently underway by its members, ensure that these get carried through, and to develop new ideas for syntheses.

A. Ryan co-supervised (along with K. Morton) a team of students from the Dalhousie Faculty of Management program's Management Without Borders (MWB) class (Sept – Dec 2015) working on a project that defined metrics for, and quantified the value and impact of, international research collaborations in the field of aquatic telemetry. The goal of the project was to compare output/impacts of individual telemetrists to that of collaborating groups. For both individuals and groups, students compared output and impacts before and after access to OTN infrastructure.

N. Beauchamp and J. Pye have met with J. Mills Flemming and MAM to collaborate on the organization of an OTN "trackathon" as part of World Fish Migration Day 2016.

Other major intra-network collaboration activities (e.g. the annual symposium/3rd ICFT) are described elsewhere in the report.

b) Interaction/Outreach to Broader Community

As Scientific Director of OTN, S. Iverson participates in numerous meetings, presentations, and workshops related to OTN. Some of these are described in detail elsewhere in this annual report. Specifically as outreach for OTN, during the reporting period S. Iverson:

- CCORU (Ottawa, Oct 2014);
- met with NSERC president, Mario Pinto, and discussed OTN as an NCE;

- accompanied by OTN HQP Jacquelin Chapman and Melissa Dick (Carleton University), participated in a special poster session at the NSERC Science Kiosk on Parliament Hill hosted by Senator Kevin Ogilvie. The annual event engages government officials on important environmental issues. While there Sara met with Ted Hewitt, head of SSHRC, to discuss OTN-Brazil (Feb 2015);
- along with Dalhousie VP Research, Martha Crago, hosted a poster session and led a tour of Dalhousie's ocean science research for John Knubley, Deputy Minister of Industry Canada (February 2015). The tour included a hands-on lobster tagging demonstration by OTN technical lead, Duncan Bates, and co-op student, Leah Strople;
- travelled twice to Brazil for several weeks in March 2015 to help get the OTN node in Brazil rolled out. While there she helped to develop a Strategic Plan and PR website, and taught a graduate course;
- led CFREF proposal writing team for Dalhouie (with Doug Wallace (MEOPAR), Julie LaRoche and Aldo Chircop);
- represented OTN during a panel discussion on the coordination of ocean science in Canada at the 49th Congress of the Canadian Meteorological and Oceanographic Society (CMOS) in Whistler, BC (Jun 2015);
- was an invited speaker at the Science in Japan forum/NOAA/AAAS meetings (Wasington DC, Jun 2015);
- gave an invited plenary talk on the benefit of networks to telemetry science ("The Potential of Networking to Transform Aquatic Animal Telemetry Science") at the 3rd ICFT (Jul 2015, see above);
- gave an invited graduate seminar at U Windsor (Sep 2015);
- along with F. Whoriskey participated in the CFI-sponsored ERA-Can+ symposium and meetings held at Dalhousie (Sept 24-25 2015). The meeting involving the EU, US, and Canada focused on the importance of strategizing arctic and marine infrastructure, the sustainability of networks and infrastructure, funding regimes, international collaboration, etc;
- along with F. Whoriskey was invited to a meeting with Trevor Swerdfager (Assistant Deputy Minister Ecosystems and Fisheries Management) to provide him with a comprehensive overview of OTN, its funding mechanisms, and data policy/management (Sep 2015). The meeting opened the lines of communication between OTN and DFO. DFO wants to return to a leadership role in coordinating science activities and build capcacity through partnerships with organizations like OTN. T. Swerdfager is planning a meeting of network heads in the near future and a DFO science summit in 2017;
- met with U.S. Ambassador to Canada, Bruce Heyman, to tour OTN HQ and discuss US-Canada partnerships during a special presentation (Sep 2015);
- chaired a session on coordinating sensors in robotics at the ERA-Can+ meetings and promoted OTN cooperation (Canada and EU) meetings in Lisbon, Portugal (Oct 2014);
- along with OTN Council chair, Peter Harrison, participated in a panel session during a CFI workshop in Ottawa (Oct 2014) that brought together representatives of the national research facilities that have received funding under the CFI's Major Science Initiatives (MSI) Fund to share MSI experiences and lessons learned; and

- participated in the Canada-Europe Working Session on Oceans and promoted OTN activities in Barcelona, Spain (Nov 2015). The working session brought together Canadian and European organizations interested in collaborative research and technological development in the ocean observatory sector with an overall goal to form working groups in areas of mutual interest, that could respond to future Horizon2020 Marine and Atlantic funding opportunities.

F. Whoriskey participates in meetings, presentations, and workshops related to Network activities, both global and Canadian. His engagement at the international level serves NSERC's mandate to promote Network activities. During the reporting period F. Whoriskey:

- travelled to Huningue, France, for the inagural Atlantic Salmon Summit on the restoration of the Rhine and challenges involved in attempting to open pathways for fish migration in the river (Oct 2015);
- met with social scientists from the Royal Embassy of Thailand at OTN HQ to discuss potential partnerships and deployments in SE Asia (Sept 2015);
- attended the joint Marine Technology Society and the IEEE Oceanic Engineering Society (Ocean's '15) conference (Washington, DC, Oct 2015). Fred made two presenations on OTN: one during the IOOS-leg IGNITE session rated by OTN Council member Zdenka Willis as "outstanding" (http://www.ioos.noaa.gov/oceans15mts/fred_whoriskey.htm) and the other as chair of a session on bioacoustics. Fred also met with members of the Smithsonian Institute on a joint proposal for IMCC 2016 in Newfoundland;
- presented on OTN in Brussels at the launch of the Blue Growth Collaborative projects under the Galway Statement and Horizon 2020 in Brussels in April. The event brought together the project coordinators and partners, from the EU, the U.S., and Canada, as well as from Brazil and South Africa to discuss transatlantic scientific cooperation (April 2015).

Other:

His Excellency the Right Honourable David Johnston met with Dalhousie President Richard Florizone and spoke at a panel discussion on innovation ecosystems at the Steele Ocean Sciences Building (OTN HQ) in April. During the course of his visit, the Governeror General wrote a thank-you to OTN and T. Rounds for drawings her children had created for him.

Clerk of the Privy Council Visits Dalhousie: Canada's top civil servant was in Halifax for the annual Public Service of Canada meeting on August 24. During her visit, Janice Charette toured Dalhousie's ocean research facilities, including OTN headquarters.

The Chinese Academy of Science also visited Dalhousie in May to discuss possible ocean science partnerships.

Duncan Bates (OTN HQ) presented OTN work during the 22nd Annual Fishermen & Scientists Research Society (Feb 2015, Halifax), which gathers researchers and commercial fishers in Atlantic Canada to share knowledge and enhance cooperation. Fishers were encouraged to pick up a database of OTN station locations compatible with OLEX, the navigation, fishery plotting, and ocean mapping system used by the majority of commercial vessels in the region.

D. Bates and Dustin Schornagel (new OTN HQ) presented on OTN at the 2015 Fishermen's Forum hosted by the Gulf Aquarium Marine Station in (Oct 2015, Antigonish, NS). This annual two-day workshop brings together fishermen, academic researchers, government officials, and non-government organizations in Nova Scotia, particularly the Gulf coast, who have an interest in the effects of climate change on the fisheries and forming collaborations to conduct climate change research.

A. Ryan presented an overview of the OTN and its research to staff of the Ecosystems Management branch (Species at Risk, Fisheries Protection, and Oceans and Coastal Management departments) of the Canadian Department of Fisheries and Oceans at the Bedford Institute of Oceanography as part of the branch's all staff day events (Oct 2015). The aim was to bring more awareness of some of the interesting OTN projects happening in the Atlantic region and to discuss the potential for OTN to broaden and strengthen collaboration with DFO.

8. Dissemination of information and results

a) Refereed journal articles (0 total) – accepted/published

(refer to Project 4.11)

c) Conference presentations (0 total) – invited

(see sections 5b and 7b)

9. Other contributions and deliverables

a) Radio or television interview or contribution to a programme/documentary, etc.

As part of the launch of the June 2015 issue of *Science* featuring the OTN-led review on global marine and aquatic telemetry research, S. Iverson was featured on the weekly *Science* podcast disussing OTN's role and global telemetry activities and was also interviewed for several newspaper pieces. The article continues to be regularly consulted online and has received a total of 28,017 downloads from the *Science* website alone and is ranked in the 99th percentile of research outputs and top 5% of all research outputs scored by Altmetric (http://www.sciencemag.org/content/348/6240/1255642.full.pdf).

F. Whoriskey interviewed with CBC radio Halifax and the Daily Planet on his experience tagging the first satellite-tagged Atlantic torpedo ray off the coast of Nova Scotia.

The OTN was featured on an episode this season of the Amazing Race Canada where participants made a stop in Halifax for a series of "local" challenges. In one challenge, teams captured, banded, and tagged Atlantic lobsters with tracking transmitters, part of OTN's study on lobster movements in Nova Scotia waters and beyond. The task took place in Dalhousie University's Aquatron Laboratory. The episode aired July 29, 2015 (Recap: theamazing: racecanada.ctv.ca/recaps/episode-4-we-know-where-they-live; exclusive video: theamazingracecanada.ctv.ca/Video).

In 2014 CBC's Land and Sea nature series filmed the blue shark tracking study (B. Davis, F. Whoriskey) with much the same focus as the Rick Mercer Report (2014). "Tracking an Ancient Predator" follows Brendal Davis (OTN researcher) and her Dalhousie University students as they tag and track blue sharks

to learn about their migrations, behaviour and survival. The documentary aired March 1, 2015 (cbc.ca/landandsea).

b) Invited or contributed open-to-public presentation/contribution

OTN HQ (N. Beauchamp, M. Weng and A. Ryan) and OTN HQP (Xavier Bordeleau and Danielle Moore) participated in a lobster tagging demonstration as part of Doors Open Halifax 2015 (6-7 June). Public interest was high, with approximately 1000 people passing through each day.

c) Invited or contributed presentation/contribution at a workshop

OTN (N. Beauchamp and A. Ryan) attended a round table discussion on science, technology and public policy hosted by the Institute for Research on Public Policy (IRPP). The event brought together academic scientists and engineers, business leaders, senior public servants and other stakeholders for a discussion on how scientific knowledge and technological expertise should be used by governments to inform the development of legislation, policy and regulation. Main themes included effective communication, building trusting relationships, and reinstating the science-policy interface and structures.

e) Awards received

S. Iverson and F. Whoriskey each received the Destination Halifax Ambassador Award for their efforts to secure Halifax as host destination for the 3rd ICFT.

OTN received a Gulf (of Mexico) Guardian Award for its support of Cory Diaz's *Utag for iTAG* program. Elementary student Cory Diaz is the principal winner of the Gulf Guardian Award for her crowds-sourcing funding campaign to raise money to pay for electronic fish tags to be used in the Gulf of Mexico.

l) Internet publishing, portal, blog, electronic publications

OTN executives hosted an AMA (Ask Me Anything) on the science subforum of the popular social networking platform, Reddit, which is ranked number 34 in most popular websites globally. The post received 554 "upvotes" (Apr 2015)

m) Anything else that isn't a primary publication that has you communicating with others

Meeuwig, J. J., Harcourt, R. G., & Whoriskey, F. G. (2015). When Science Places Threatened Species at Risk. *Conservation Letters*, *8*(3), 151–152. http://doi.org/10.1111/conl.12185

The OTN (F. Whoriskey, D. Bates) was featured in a Halifax magazine article (March 2015 – "Brain Power: Eyes on the Ocean." http://halifaxmag.com/cover/brain-power-2/

Wave Glider article published: International Ocean Systems Mar/Apr 2015 "A New Way to Track Fish" http://www.intoceansys.co.uk/articles-detail.php?iss=0000000047&acl=0000000413

Environment Coastal and Offshore (ECO) magazine March 2015 "Canadadian Wave Glider Helps Track Marine Species" http://digital.ecomagazine.com/publication/?i=247321

Special issue of MTS Journal: Impact of Data on Ocean Observing Systems and lessons learned

10. Collaborations with industrial and government partners

a) Partners

The Canada Foundation for Innovation, through its support of the Ocean Tracking Network Global (based at Dalhousie University) and Dalhousie University are the major collaborators with the Ocean Tracking Network Canada Secretariat.

b) Contributions

Name of supporting organization: **CFI**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	**
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	**
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Indirect costs:

1) Salaries of managerial and administrative staff that assist the Secretariat:

- Lenore Bajona, Director of Data Management
- Jon Pye, OTN Portal Manager

5) Provision of services through use of data management team and website assistance.

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Dalhousie University**	**Year 6** (2015)
Cash contributions to direct costs of research	12, 000
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	2850
2) Salaries of managerial and administrative staff	**
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Direct costs:

1) Salaries for scientific and technical staff

- Salary support for teaching replacement (limited term appointments) for Scientific Director S. Iverson ($12,000).

Indirect costs:

1) Use of organization's facilities

- Annual rental of office space for OTN secretariat (S. Iverson, A. Ryan, and N. Beauchamp), 300 square feet at $9.50sq/ft. $2850;

2) Salaries of managerial and administrative staff and other:

- Dalhousie is contributing administrative, legal, and other support services (basic administrative

and infrastructure support, services of the research grants, and financial services offices, insurance, security, library access etc.). This support constitutes an additional in kind contribution of approximately $210,718 (for years 1 to 7).

Name of supporting organization: **VEMCO**	**Year 6** (2015)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	
2) Donation of equipment, software	
3) Donation of material	
4) Field work logistics	
5) Provision of services	
6) Other (specify):	
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	
2) Salaries of managerial and administrative staff	
3) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no