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

Annual Reports Year 5 (2014)

NSERC Research Network Grant: NETGP 375118 – 08

Sara J. Iverson et al.

Table of Contents

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). Phase II builds on the work of Phase I. To achieve the evolved aims of OTN Canada, a conceptual framework of scientific questions was established to more strategically align the related research activities within that framework and to inform ocean governance. In Phase II, the research questions being addressed across OTN Canada (and international partners) are broadly structured around three major integrated "framework questions" (FQs), under which projects are organized (Table 1). Many activities will 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/or projects and subprojects, which include methodologies and approaches that can inform the three FQs. This overall organization ensures a conceptual understanding of how projects are interrelated, illustrates how these can be most effectively integrated across the Network to best address OTN Canada's mission, and allows rapid dissemination to interested parties of all individual research projects and programs. This approach also fosters a breadth of training opportunities and exposure for HQP.

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

Researchers have accumulated an outstanding track record of first-rate science and have developed an integrated Canada-wide research network with increasing international reach now in Phase II of Network activities. 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 80 of these trainees. Details of all the projects and Network integration are described in each of the individual reports that follow the Network Overview.

Integration of the Network within and across FQs and CCAs continues to increase and evolve through directed workshops and meetings, data exchange and joint publications and presentations, exchange of HQP, and integrated field exercises.

2.1 HQP exchange highlights

Dr Mélanie Béguer continues her research at Dalhousie University (having relocated from Laval in fall 2013) to strengthen ties between the American Eel project (Project 4.5) and physical oceanography studies (Project 4.1).

Montana McLean began PhD work on white sturgeon migration (Project 4.14) in the Pacific Arena under Dalhousie PI Glenn Crossin. McLean completed her Masters with OTN during Phase I at Acadia on Atlantic sturgeon (Project 4.6).

Numerous HQP have been able to participate in outreach, exchange and conference activities as described in 4.16.

2.2 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). The figure below (created by HQP Marianne Marcoux) illustrates collaborations initially described between PIs in the Phase I proposal and those described in the Phase II proposal. This diagram will be updated as the Network progresses to demonstrate growth and integration during Phase II.

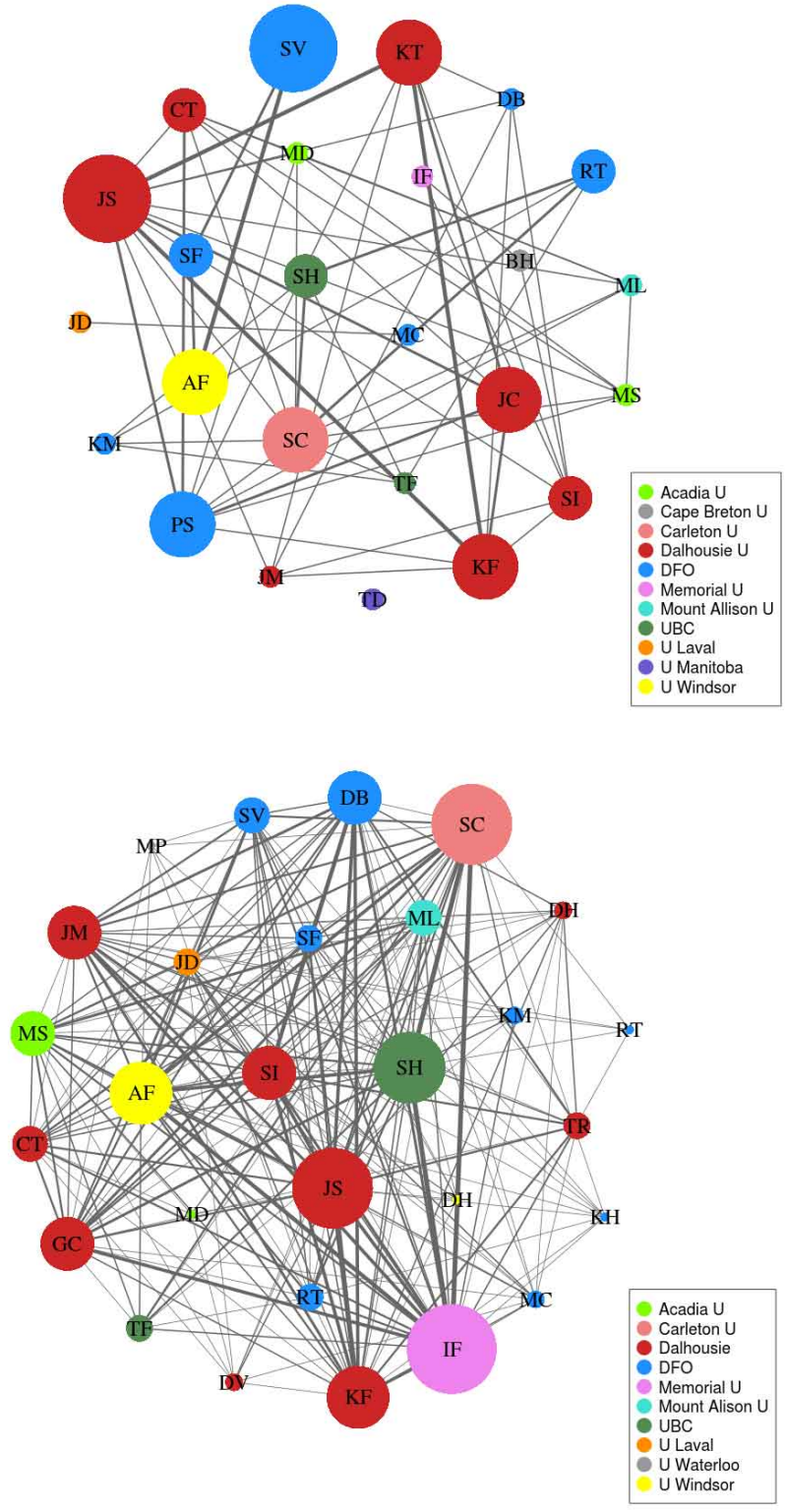

Figure 1. Comparison of OTN Canada integration as described in Phase I (top) and as described at the initiation of Phase II (bottom). Developed and presented by HQP Marianne Marcoux at the 2014 OTN Canada Symposium.

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 summarizes the HQP who have been supported by the Network during 2014.

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	**Total (100% support from OTNC)**
4.1	-	-	5 (1)	-	2 (2)	**7 (3)**
4.2	5 (0)	2 (0)	1 (1)	-	3 (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	6 (3)	3 (0)	-	-	-	**9 (3)**
4.7	-	1 (1)	-	-	2 (0)	**3 (1)**
4.8	-	2 (0)	1 (1)	1 (1)	1 (1)	**5 (3)**
4.9	-	-	2 (1)	1 (0)	-	**3 (1)**
4.10	-	2 (2)	2 (1)	-	1 (1)	**5 (4)**
4.11	-	1 (1)	2 (2)	1 (0)	1 (0)	**5 (3)**
4.12-4.15	6 (0)	4 (0)	10 (2)	6 (0)	1 (1)	**27 (3)**
Total (receiving 100% support from OTNC)	**23 (3)**	**16 (4)**	**24 (9)**	**9 (1)**	**12 (6)**	**84 (23)**

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, including the transfer of research results within the Network and to the general scientific community. DFO has two voting members (A. Vezina, DFO representative, and S. Vagle, Arctic Arena representative) on the NSERC Scientific Advisory Committee (SAC) and ten of the 27 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)

None of the research programs of the OTN Canada Network could take place without the significant contribution of infrastructure support from 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 the OTN Canada Symposia to better keep key international partners abreast of 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 continues to have a number of industry collaborators, both national and international. These industry collaborators, such as VEMCO, Satlantic, Romor, Lotek, the Sea Mammal Research Unit, and others, have been integral in helping solve problems, develop new technology, construct needed equipment, and brainstorm about better ways to use it. A number of new industry partners were established during the reporting year 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 whom the OTN Canada PIs and collaborators are associated provide further infrastructure and support, including personnel support, to conduct the Network's research, sponsor HQP, and host various other activities. These are apparent throughout, and detailed in, individual project reports. Eight universities listed in *Times Higher Education* World University (top 200) Rankings are primary collaborating institutions under the OTN umbrella. University of British Columbia and University of Victoria are ranked 32nd and 173rd respectively.

5. Dissemination and Other Contributions

5.1 Publications and presentations

OTN Canada research is making impacts locally, regionally, nationally and abroad. Network members regularly present to and exchange information among government scientists, other research networks, ENGOs and private industry. 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 and implementation as well as serve to build important relationships with communities on which research has direct implications. Network members continue to share research insights and results with stakeholders including grade-school groups, local communities, academic and industry partners, and government officials through such communications channels as workshops and lectures (outside the Network); public presentations; newspaper, television and radio interviews; and through affiliated organizations' newsletters and other media.

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	6	0	1	0	4	6	3	3	0	1	7	39	**97**
Conference presentations (invited and contributed)	17	3	6	0	8	13	4	3	1	6	4	50	**196**

Table 4. Summary of dissemination (partner meetings, public outreach of other deliverables) 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 as part of collaborations with non-OTN members	3	8	5	6	4	4	7	2	2	3	1	12	**57**
Public dissemination (e.g., interview, community or school presentation, book)	0	6	2	1	0	6	3	0	6	8	3	22	**57**
Other (e.g. facility tour, meeting with government official)	0	6	0	0	0	0	0	0	0	0	0	2	**8**

5.2 Newsletter and Website

The OTN newsletters share news and events from Canadian and Global perspectives. It 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 deployment, data, and technology updates as well as conference dates and calls for proposals and now stands at 12 pages, almost double the content from the first issue; however, the newsletter now competes with the annual report in terms of reporting breadth and scope. As such, the Network is in a better position to produce ~monthly reports thus keeping the Network more visible by publishing more frequent, timelier and shorter newsletters beginning in the new-year. Analytics will be tracked and compared to semi-annual publications to enhance the quality of newsletter content and drive better engagement with OTN digital media per the communications strategy.

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. Hardcopies are distributed during promotional events and to visiting delegations.

The OTN website (oceantrackingnetwork.org) underwent a significant redesign (again) in 2014. Dalhousie Computer Science student Timothy Arrott was hired as a full-time summer co-op student (50% salary from N.S. Government, 50% from CFI) dedicated to migrating the OTN website from Plone to the more user-friendly WordPress (Figure 2). The 2013 redesign used Plone. Redesign was facilitated in consultation with the Scientific Director and Communications Officer. All targets were met and analytics describe better overall engagement compared to the previous year including greater overall usership and longer session duration,

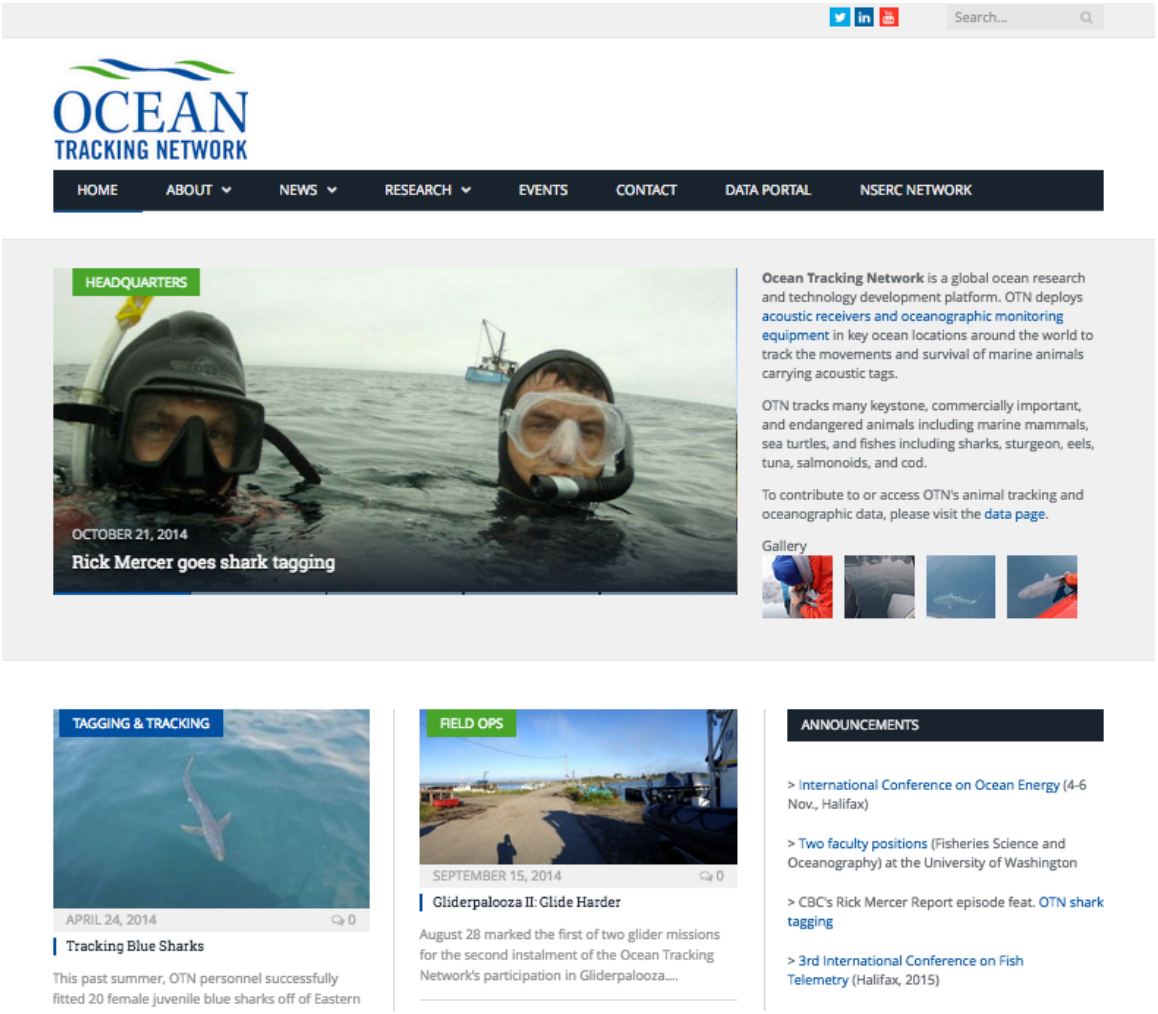

Figure 2: OTN website landing page (launched July 2014).

5.3 Data management/sharing

The OTN Data Centre made significant strides in management of OTN research data in 2014. While not a formal project of OTN Canada, the work of the data team is integral to the success of OTN Canada research and is leading to a deeper understanding of animal movement by OTN Canada researchers. As such it warrants mention here. Several data tools were developed and disseminated to the Network in the form of a Data Workshop and follow-up online tutorials.

5.4 Other contributions and deliverables

The OTN Canada Network continues to make large contributions to various outputs such as productions of webpages, radio and television appearances, and documentary filming. There have also been many outputs of newspaper and magazine stories, technical reports, invited conference and public presentations, and input into public advisory meetings and documents, including providing expert advice and consultation. 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 and are detailed in the individual reports that follow.

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 where required 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. Details of reprofiling requests are documented in the individual projects (see also 4.16)

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

1. Project Number: 4.1

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

3. Project Leaders: Katja Fennel (Dalhousie U), 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: Keith Thompson (Dalhousie U), Blair Greenan (DFO-Bedford Inst, Dalhousie U)

4. Public summary of report

The ocean is becoming warmer, is losing oxygen and is becoming more acidic – changes that will have important and possibly dramatic implications for marine ecosystems. The biogeochemical environment is changing especially rapidly in coastal regions including in Atlantic Canada, a region with rich fishing grounds that supports significant fishing revenue. This project focuses on the effects of physical and biogeochemical ocean changes on species in the Atlantic Canada region. We developed numerical models to simulate the physical and biogeochemical environment encountered by animals in Atlantic Canadian waters, and numerical models to simulate Atlantic eel migrations and Atlantic salmon population decline. Further, we demonstrated the use of these numerical models in several applications with direct implication for the management of marine resources. By combining observations and model-simulated projections of oxygen decline on the Scotian Shelf with known habitat requirement of the endangered Atlantic wolffish, we showed that oxygen is a likely factor in the observed habitat contraction and where habitat will likely contract in the future. By optimizing a model of Atlantic salmon populations we derived temporal trends in mortality of different age-classes and showed that survival during the first year at sea is crucial to population recovery. We used an individual-based model of the migration of American eel in the Gulf of St. Lawrence (GSL) to examine the role of physical conditions and swimming behaviours on the eels' migration in the Gulf. We also used a similar model to estimate the over-wintering area of Atlantic sturgeon.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Laura Bianucci	RA	100	100	1 Sept 2010	31 Oct 2014
Research Topic: Biogeochemical modeling in the Atlantic Canada region; Projections of suitable habitat					
Rui Zhang	PhD	50	3	1 Jan 2014	31 Mar 2015
Research Topic: Simulation of Atlantic salmon population					
Angela Kuhn	PhD	50	50	1 Sept 2013	31 Mar 2015
Research Topic: Biogeochemical model optimization for the North Atlantic and the Atlantic Canada region					
Liuqian Yu	PhD	50	50	1 Sept 2013	31Mar 2015
Research Topic: Biogeochemical data assimilation for the Atlantic Canada region					
Kyoko Ohashi	RA	100	100	2 Oct 2010	31 Mar 2015

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Research Topic: 3D circulation over eastern Canadian waters, effect of physical environment on migration of American eels, estimation of satellite tag pop-up positions for Atlantic sturgeon					
Shiliang Shan	PhD	100	10	1 Oct 2010	31 Mar 2015
Research Topic: Numerical study of circulation and hydrography on the Scotian shelf and shelf break					
Jorge-Urrego Blanco	PhD	100	100	1 Aug 2011	30 Sept 2014
Research Topic: Subtidal circulation over the northwest Atlantic Ocean using OPA					

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 to play 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. We proposed 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

The manuscripts of previous OTN MSc student Karl Lagman and previous OTN PDF Paul Mattern have been published. Their work has been described in previous progress reports.

OTN PhD student Rui Zhang has developed an age-structured model of the Atlantic salmon population and implemented a novel method for optimizing the population's survival and mortality parameters through time. These age-dependent parameters are crucial in determining the evolution and viability of the Atlantic salmon population. Rui has applied the model to the last 40 years of available observations and was able to get an excellent fit between model and observations. His results indicate that a systematic decline in survival rates in the "first year at sea" age group is responsible for the observed decline. While the explanation is not new, it is not universally accepted. Rui's results provide further evidence, using a novel approach, that survival during the first year at sea is the crucial factor. Rui's model and method allow testing scenarios and informing management decisions. For example, the Atlantic Salmon Federation is currently subsidizing fisherman to forgo harvest of mature Atlantic salmon in Greenland waters. Rui's next step will be to assess the effect of this decision on the Atlantic salmon population. A manuscript describing his model, method and initial results is in preparation.

Former OTN summer student Hannah Blanchard has compiled a survey of habitat requirements (temperature, depth, oxygen, pH) for commercially important and endangered species in the Atlantic Canadian region in summer 2013. This work was the foundation for a manuscript presently submitted to Fish and Fisheries.

Hannah's compilation of habitat requirements has also facilitated a case study by OTN RA Laura Bianucci demonstrating the use of a coupled physical-biological model (developed for the Atlantic Canada region during OTN Phase I) for habitat analysis and projections under global warming scenarios. Laura has shown that the relatively high oxygen requirement of Atlantic wolffish, a species listed as "special concern" under COSEWIC, likely explains the observed contraction of habitat on the Scotian Shelf from pre- to post-1980s. While temperature and bottom substrate are recognized as primary factors defining optimal habitat, these factors have not changed from pre- to post-1980s and thus do not explain the observed contraction of occupied habitat and the decline in wolffish abundance. By combining observed oxygen concentrations and model-simulated fields of projected future oxygen distributions, Laura was able to show 1) that the observed habitat contraction is consistent with past oxygen changes on the Scotian Shelf (pointing to oxygen as a major factor), and 2) that simulations of future oxygen distributions suggest a further contraction of optimal wolffish habitat, especially in locations that are currently population hot spots, including the planned St. Ann's Marine Protected Area on the Scotian Shelf. This case study demonstrates the use of biological model simulations and projections for marine management, in particular when anticipating te effects of future changes due to global warming, deoxygenation and acidification. The wolffish case study is submitted for publication to the ICES Journal of Marine Science.

RA Kyoko Ohashi has developed an individual-based model (IBM) for simuating the American eel's movement in the GSL. The IBM consists of a numerical particle-tracking scheme using three-dimensional fields of currents, temperature, and salinity produced by a shelf circulation model for the eastern Canadian shelf. Simulations using the IBM were used to assess the role of various types of active swimming behaviour in the eels' migration through the St. Lawrence Estuary and the GSL. The results of these experiments were summarized in a manuscript that has been submitted recently for publication to Atmosphere-Ocean. Another manuscript is being prepared, with RA Melanie Beguer of Project 4.5 as first author, about experiments using the IBM focusing on the eels' transit time across the GSL. Kyoko also started work on estimation of the Atlantic sturgeon's over-wintering area in the Gulf of Maine. Researchers from Project I.2.3 attached archival tags to Atlantic sturgeon in the Saint John River during the summer of 2012. The tags became detached from the fish and "popped up" (reached the ocean surface) between February and April of 2013. The determination of a tag's location through contact with a satellite can take place up to several hours after pop-up, by which time the tag would have been carried by currents away from the pop-up location. In order to estimate the pop-up location, the numerical particle-tracking scheme (that is also part of the American eel IBM) was run backwards in time from the time of first satellite detection of the tags. Results of these experiments have been shared with Andrew Taylor and Dr. Matt Litvak (Mount Allison University) of Project 4.6 for possible inclusion in a manuscript they are preparing.

PhD student Jorge Urrego-Blanco developed a coupled ice-ocean model for eastern Canadian waters by coupling a two-category sea-ice model to a nested-grid ocean circulation modelling system. The presence of sea ice can significantly affect the vertical structure of the water column via brine rejection and air-sea fluxes of heat and momentum; the vertical structure of the water column, in turn, influences primary production and has implications for the local ecosystem in the GSL. The coupled ice-ocean model was used to study the distribution and variability of sea ice in the GSL, which is an

area with a highly productive ecosystem. Jorge has had two manuscripts published and has submitted two more manuscripts during the reporting period. Jorge completed his PhD degree requirements in September 2014.

PhD student Shiliang Shan has been studying ocean dynamics over the Sable Gully (a submarine canyon at the edge of the Scotian Shelf that is a federal Marine Protected Area) using the 5-level nested model that he has developed. The model was also combined with a numerical particle-tracking scheme to simulate the movement of particles into and out of the Gully, as a first step towards a better understaing of the movement of nutrients and marine animals in this area. Shiliang has had two manuscripts published during the reporting period, and defended his dissertation proposal in September 2014. Shiliang developed a nested-grid circulation model for the inner Scotian Shelf. The innermost submodel covers the OTN Halifax Line. The model is used to study the Nova Scotia Current and coastal upwelling. The results were presented in the 48th CMOS Congress. In collaboration with the PIs and HQP on the Ocean Observation Component, the model results will be compared with the observations made on the OTN Halifax Line. In collaboration with the PIs and HQP on the American Eel project, Shiliang also worked on the seaward migration of American and European eels in the open ocean using a coupled bio-physical particle tracking model. The particle tracking model includes background ocean currents and various migratory behaviors. The eel is tracked in a quasi three dimensional fashion to include diel vertical migration and energy expenditure calculation. The influence of oceanic current on the eel migration is quantified. The results were presented in the International Eel Symposium 2014. A manuscript is being prepared for publication in the ICES Journal of Marine Science.

Following is the list of manuscripts to be prepared in 2015:

Index	Topic	Authors (tentative)	Submission Date
1	Effect of physical conditions on migration of American eels in the Gulf of St. Lawrence	Melanie Beguer, Kyoko Ohashi, Jinyu Sheng, Julian Dodson, Martin Castonguay	May 2015
2	Numerical simulation of marine animals on the Scotian Shelf	Kyoko Ohashi, Jinyu Sheng, Shiliang Shan, and collaborators	August 2015
3	Atlantic sturgeon over-winter behavior, distribution and habitat occupancy	Andrew Taylor, Matthew Litvak, Kyoko Ohashi, Jinyu Sheng	February 2015
4	Oceanographic conditions in the Bay of Fundy and their impacts to the migration of Atlantic sturgeon	Kyoko Ohashi, Jinyu Sheng, Mike Stokesbury, and collaborators	October 2015
5	Circulation and variability over the central Scotian Shelf	Shiliang Shan, Jinyu Sheng and collaborators	February 2015

Following is the list of conference presentations to be made in 2015:

Index	Conference	Authors	Conference Dates
1	International conference on modeling the Ocean	Jinyu Sheng, Kyoko Ohashi, Shiliang shan	June 2015
2	Canadian Meteorological and	Kyoko Ohashi, Jinyu Sheng	June 2015

	Oceanographic Society		
3	Annual meeting of the American Fisheries Society	Kyoko Ohashi, Jinyu Sheng	August 2015
4	OTN annual conference	Shiliang Shan, Jinyu Sheng	
3	Estuarine and Coastal Modelling	Jinyu Sheng and Kyoko Ohashi	November 2015

c) Significant deviations

One deviation from the originally stated objectives is the inclusion of the Atlantic wolffish case study. We chose this species because it turned out to be the most oxygen-sensitive based on our literature review, and because of the well-documented contraction of habitat on the Scotian Shelf. Atlantic wolffish serves as an excellent example for how models that were developed with OTN funding can be used as tools in marine management.

d) Coordination and integration

The projects co-leads Dr. Fennel and Dr. Sheng have worked together closely in all aspects of the project and served on each other's students' advisory committees during the report period.

e) Scientific and/or engineering significance

Models developed by this project and during the previous OTN Phase are useful tools for marine management. For example, the population model of Atlantic salmon developed in this project is being used to investigate the effect of subsidies on the Atlantic salmon population, and the case study of Atlantic wolffish decline with projection of its future habitat contraction demonstrates that additional variables (e.g. oxygen) and projections of future changes (e.g. habitat contraction due to declining oxygen trend) should be considered when planning Marine Protected Areas and in other management decisions, and provides contrete tools for doing so.

Numerical particle-tracking is a tool with potential for many useful practical applications, as it can help answer the questions "Where will this go?" and "Where did this come from?" It can 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.

Working with ocean models involves constant effort towards a more realistic representation of ocean dynamics. Using a nested-grid model to enable high spatial resolution in the inner model and implementation of sea ice are two examples of such efforts that took place during this reporting period. A better ocean circulation model will in turn contribute towards a better representation of the interaction between the physical and biological/chemical sides of oceanography.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

HQP and collaborators attended the Annual OTN Meetings in June 2014 in Ottawa as well as some of the OTN workshops that were held in conjunction. HQP presented their work in form of oral presentations and posters. Many opportunities for informal discussions arose.

A close collaboration is ongoing with PIs and HQP on the American Eel project. Dr. Julian Dodson, Dr. Martin Castonguay and Dr. Melanie Beguer closely collaborate with PI Dr. Sheng, and Dr. Beguer is now located at Dalhousie. The individual-based model (IBM) of the American eel described in Section 6b has also been used by Dr. Dodson's group in various ways. One example is to determine whether or not the concentration of eel detections along the western end of the acoustic monitoring across Cabot Strait (an exit from the GSL) actually represented the eels' preference for western Cabot Strait, or indicated a failure of instruments on the eastern end of the monitoring line. (Results of the IBM experiments suggest that the former is true.) Travel times of eels simulated by the IBM can also suggest whether or not detections of acoustic tags at the Cabot Strait line represent passages of eels or of predators that have ingested tags that had been attached to eels. Another example of the collaboration is estimation of the eels' migration paths through comparison of: 1) depth and temperature measurements made by archival tags attached to eels and 2) the bathymetry of the GSL and water temperatures simulated by the coastal circualtion model.

Collaboration started between Dr. Jinyu Sheng's group and Dr. Matt Litvak's group 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 beginning of this collaboration was coordinated by Dr. Katja Fennel; Dr. Litvak initially contacted Dr. Fennel about a possible collaboration, and Dr. Fennel recommended Dr. Sheng's group as having an ocean model that was more suited for this particular project.

Dr. Sheng and Dr. Fennel collaborated closely with collaborators from project 4.2 Ocean Observation Component, particularly on the use of glider data in model validation and Dr. Hebert and Dr. Greenan in the analysis and interpretation of oceanographic observations from the OTN moorings on the Halifax Line. Dr. Sheng and Dr. Hebert are co-supervising MSc student Matthieu Dever who is funded through project 4.2 and Dr. Fennel is a member of his supervisory committee.

They also collaborated closely with Dr. Thompson and his group in the study of the impact of environmental perferences on the migration of American eel in the northwest Atlantic Ocean.

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.

Targeted meetings inlcude two meetings with DFO scientists involved in fisheries management with HQP in Fennel's lab in summer of 2014, one by Nancy Shackell and one by Jae Choi. During these meetings the DFO scientists gave a presentation followed by presentations from the OTN HQP and a discussion.

Rui Zhang has made contact with the Atlantic Salmon Federation (ASF) to share his results and to discuss model scenario tests for assessing the effects of their salmon subsidies on the salmon population.

9. Dissemination of information and results

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

Mattern, J.P., Fennel, K., and Dowd, M. (2014) Periodic time-dependent parameters improve forecasting abilities of biological ocean models, Geophysical Research Letters 41. doi:10.1002/2014GL061178

Lagman, K., Fennel, K., Thompson, K.R., and Bianucci, L. (2014) Assessing the utility of frequency dependent nudging for bias correction in biogeochemical models, Ocean Modelling 81:25-35. doi: 10.1016/j.ocemod.2014.06.006

Shan, S., Sheng, J., and Greenan, B.J.W. (2014) Modelling study of three-dimensional circulation and particle movement over the Sable Gully of Nova Scotia, Ocean Dynamics 64: 117-142. doi:10.1007/s10236-013-0672-7

Shan, S., Sheng, J., and Greenan, B.J.W. (2014) Physical processes affecting circulation and hydrography in the Sable Gully, Deep-Sea Research II 104: 35-50. doi:10.1016/j.dsr2.2013.06.019

Urrego-Blanco, J. and Sheng, J. (2014) Study of subtidal circulation and variability in the Gulf of St. Lawrence, Scotian Shelf, and Gulf of Maine using a nested-grid shelf circulation model, Ocean Dynamics 64: 385-412. doi:10.1007/s10236-013-0688-z

Urrego-Blanco, J. and Sheng, J. Formation and distribution of sea ice in the Gulf of St. Lawrence: A process-oriented study using a coupled ocean-ice model, Journal of Geophysical Research - Oceans (in press).

b) Refereed journal articles (7 total) – submitted

Bianucci, L., Fennel, K., and Mattern, J.P. What drives phytoplankton growth during deep winter mixing? A model study for the Northwest Atlantic, Ocean Modelling (submitted).

Bianucci, L., Fennel, K., Chabot, D., and Shackell, N. Application of a coupled physical-biological model to identify essential habitat in a changing climate: Atlantic Wolffish case study, ICES Journal of Marine Science (submitted).

Brennan, C., Bianucci, L., and Fennel, K. Sensitivity of northwest North Atlantic shelf circulation to surface and boundary forcing: A regional model assessment, Atmosphere-Ocean (submitted).

Brennan, C.E., Blanchard, H., and Fennel, K. Putting temperature and oxygen thresholds of marine animals in context of environmental change: A regional perspective for the Scotian Shelf and Gulf of St. Lawrence, Fish and Fisheries (submitted).

Kuhn, A., Fennel, K., and Mattern, J.P. Model investigations of the North Atlantic spring bloom initiation, Progress in Oceanography (submitted).

Ohashi, K. and Sheng, J. 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 (submitted).

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

c) Conference presentations (3 total) – invited

Bianucci, L., Fennel, K., Brennan, K., and Blanchard, H. Resilience or vulnerability? Oxygen thresholds of marine animals on the Scotian Shelf in the context of environmental change, 4th OTN Canada Symposium, June 3-5, 2014, Ottawa, Canada.

Zhang, R. and Fennel, K. Simulating the decline of Atlantic salmon populations, 4th OTN Canada Symposium, June 3-5, 2014, Ottawa, Canada.

Ohashi, K. and Sheng, J. Using numerical particle-tracking to study the movement of the American eel and the Atlantic sturgeon, 4th OTN Canada Symposium, June 3-5, 2014, Ottawa, Canada.

d) Conference presentations (14 total) – contributed

Brennan, C., Bianucci, L., and Fennel, K. Sensitivity of northwestern North Atlantic shelf circulation to surface and boundary forcing: A regional model assessment, April 27 – May 2, 2014, Vienna, Austria.

Brennan, C., Blanchard, H., and Fennel, K. Putting temperature and oxygen thresholds of marine animals in context of environmental change in coastal seas: A regional perspective for the Scotian Shelf and Gulf of St. Lawrence, April 27 – May 2, 2014, Vienna, Austria.

Brennan, C., Blanchard, H., and Fennel, K. Putting temperature and oxygen thresholds of marine animals in context of environmental change in coastal seas: A regional perspective for the Scotian Shelf and Gulf of St. Lawrence, 46th Liege Colloquium on Low Oxygen Environments, May 5 – 9, 2014, Liege, Belgium.

Bianucci, L. and Fennel, K. Oxygen dynamics in the Gulf of St. Lawrence and on the Scotian Shelf, 46th Liege Colloquium on Low Oxygen Environments, May 5 – 9, 2014, Liege, Belgium.

Shan, S., Sheng, J., Ohashi, K., and Dever, M. A multi-nested circulation model for central Scotian Shelf: Model validation, 48th CMOS Congress, June 1-5, 2014, Rimouski, Canada.

Shan, S., Sheng, J., and Greenan, B. Modelling study of circulation and particle movement in a submarine canyon: Sable Gully, 48th CMOS Congress, June 1-5, 2014, Rimouski, Canada (poster).

Sheng, J. and Ohashi, K. Using numerical particle-tracking to study the movement of marine animals in eastern Canadian waters, 48th CMOS Congress, June 1-5, 2014, Rimouski, Canada.

Sheng, J. and Urrego-Blanco, J. Numerical study of ocean circulation and sea ice distribution over the eastern Canadian shelf, International Workshop on Atmosphere and Ocean Dynamics, April, 2014, Liverpool, United Kingdom.

Shan, S., Béguer-Pon, M., Thompson, K.R., Castonguay, M., Dodson, J.J., and Sheng, J. How Do American and European Eel Migrate to the Sargasso Sea? 144th American Fisheries Society annual meeting: International Eel Symposium 2014, August 20, 2014, Québec City, Canada.

Urrego-Blanco, J. and Sheng, J. Study of sea ice dynamics in the Gulf of St. Lawrence using a nested-grid ocean-ice model, 48th CMOS Congress, June 1-5, 2014, Rimouski, Canada.

Ohashi, K. and Sheng, J. Using numerical particle-tracking to study the movement of the American eel and the Atlantic sturgeon, 6th International Workshop on Modeling the Ocean, June 23-27, 2014, Halifax, Canada.

Shan, S., Sheng, J., and Greenan, B. Modelling study of circulation and particle movement in a submarine canyon: Sable Gully, 6th International Workshop on Modeling the Ocean, June 23-27, 2014, Halifax, Canada.

Urrego-Blanco, J., and Sheng, J. Study of sea ice dynamics in the Gulf of St. Lawrence using a nested-grid ocean-ice model, 6th International Workshop on Modeling the Ocean, June 23-27, 2014, Halifax, Canada.

Ohashi, K. and Sheng, J. Numerical study of the effect of the physical environment on the movement of the American eel in the Gulf of St. Lawrence, High Performance Computing Symposium 2014, June 25-27, Halifax, Canada (poster).

Shan, S. and Sheng, J. Examination of circulation and particle movement in a submarine canyon: Sable Gully, using a high-resolution ocean circulation model, High Performance Computing Symposium 2014, June 25-27, Halifax, Canada (poster).

Urrego-Blanco, J. and Sheng, J. Study of sea ice dynamics in the Gulf of St. Lawrence using a coupled ocean-ice model, High Performance Computing Symposium 2014, June 25-27, Halifax, Canada (poster).

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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 (Laura Bianucci, Catherine Brennan and Shilang Shan) and researchers tagging Atlantic salmon (John Kocik) continued. Notably, the number of collaborations expanded this year, adding Carrie Byron to the Atlantic salmon group and the researchers in the MEOPAR Whales Habitat and Listening Experiment (Chris Taggart, Kim Davies and Mark Baumgartner) who are now using OTN ocean glider data to assess endangered North Atlantic right whale habitat. Dalhousie's Marine Observations Support Team (MOST) sustained an effective program of ocean glider operations, sampling the ocean interior of the Scotian Shelf 171 glider days during the reporting period, while successfully integrating new sensors (such as the 300 kHz echosounder) 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 second year in Gliderpalooza, an international program to sample the eastern seaboard of the United States and Canada, with 34 ocean gliders from 17 institutions in the water simultaneously. All the ocean glider data are shared through web-based data presentations and regular interactions 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	End Date
Matt Beck	MSc	100	0	Sep 2010	May 2015
Research Topic: A multiparameter approach for estimating chlorophyll a from ocean gliders.					
Cailin Burmaster	Coop student	30	0	2 Sep 2014	31 Dec 2014

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Kacie Conrad	Coop student	30	0	5 May 2014	22 Aug 2014
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Brad Covey	RA	60	0	1 Jul 2014	NA
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Mathieu Dever	PhD	100	100	Jan 2011	Dec 2015
Research Topic: Dynamics of the Nova Scotia Current and its Relationship with Atlantic Salmon Migration Patterns over the Inner Scotian Shelf.					
Delphin Durette-Morin	Coop student	30	0	6 Jan 2014	25 Apr 2014
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Sue L'Orsa	RA	50	0	26 May 2014	NA
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Jon Pye	RA	20	0	1 Oct 2013	5 May 2014
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Gennavieve Ruckduschel	MSc	30	0	1 Jun 2014	1 Jun 2016
Research Topic: Right whale habitat: distribution and dynamics of copepod species in Roseway Basin.					
Jude Van der Meer	Coop student	30	0	6 Jan 2014	25 Apr 2014
Research Topic: Ecosystem monitoring on the Scotian Shelf.					
Kristen Wilson	Coop student	30	0	1 Oct 2013	20 Dec 2013
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. Graduate student Matt Beck is working on his MSc thesis developing new estimates of chlorophyll from glider measurements. This involves extensive skill in programming and in the application of hydrological optics. Mathieu Dever is a PhD student fully supported by OTN. His role is to process all physical oceanographic observations collected as part of 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 Ruckduschel's MSc thesis will focus on using the echosounder data from the gliders to examine the distribution and dynamics of copepods in Roseway Basin. Brad Covey was hired this year to replace Jon Pye as our Information Technology specialist. He creates and maintains databases, programs missions for the gliders, maintains computer hardware, and maintains the OTN glider web presence. To date, he is being trained in house but will soon travel to Webb for formal training. Sue L'Orsa is another new hire whose primary role is glider preparation, maintenance and deployment. She is trained in house by long-time technician Adam Comeau, but is scheduled for training by Webb soon. Glider operations, data management and validation sample processing requires extra hands. Our group regularly hires co-op students, such as Cailin Burmaster, Kacie Conrad, Delphin Durette-Morin, Jude Van der Meer, and Kristen Wilson, to participate in our varied activities, giving them valuable training and skills for the future.

6. Progress towards objectives/milestones

a) Overall objectives

One of the major questions framed by OTNC 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

Water mass properties were measured systematically along the Halifax Line, and sporadically in Roseway Basin, using Webb slocum gliders (Figure 1). The two OTN gliders were in the water for 171 days and flew a combined distance of just over 4000km, collecting over 10 million data points along the way. Figure 2 is a Gantt chart of deployments for the reporting period and shows the time periods when the gliders were active. Figure 3 is heat map of the glider satellite connections showing the locations of

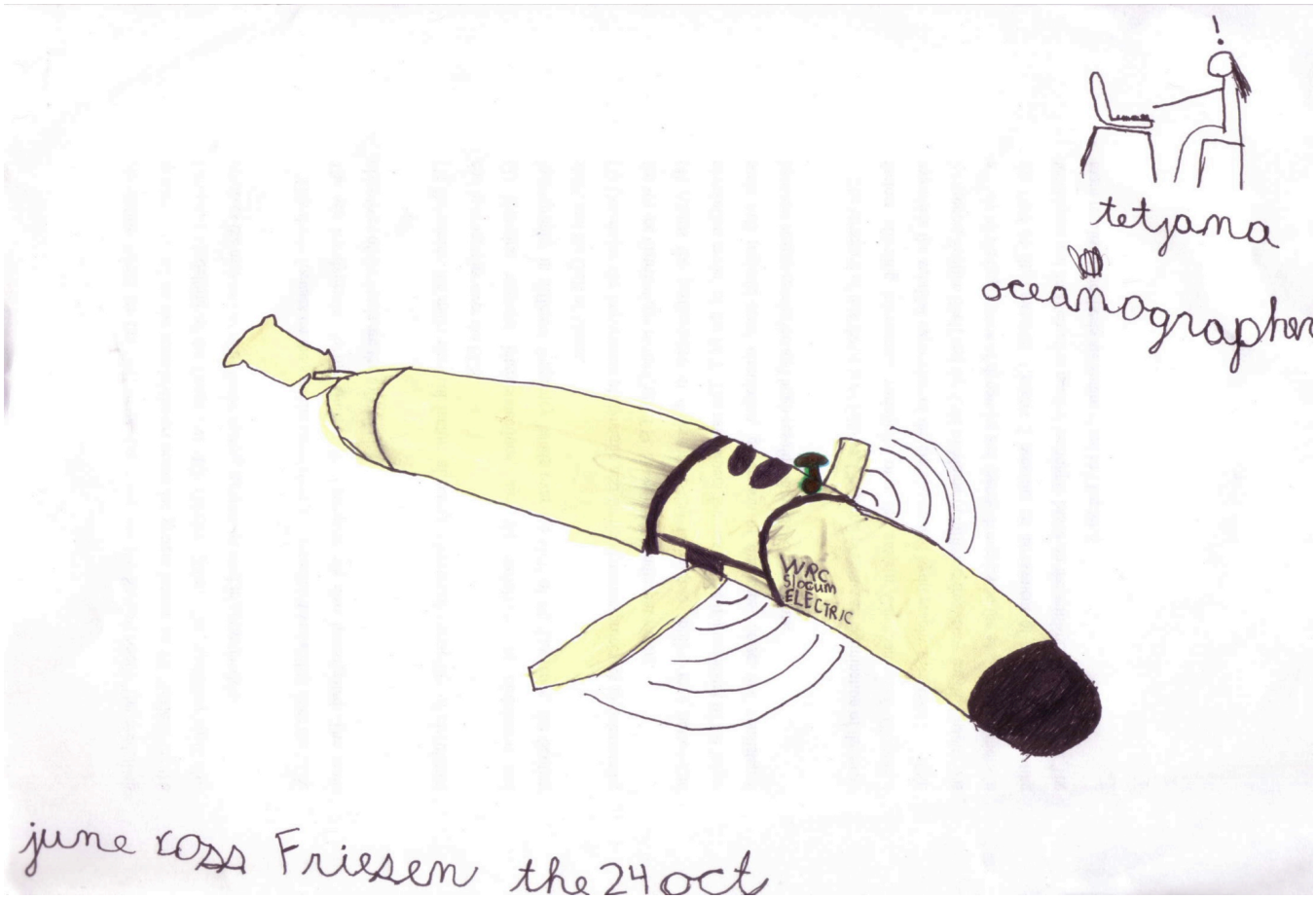

Figure 1. Pictorial representation of OTN201 equipped with a 300kHz echosounder.

the missions.

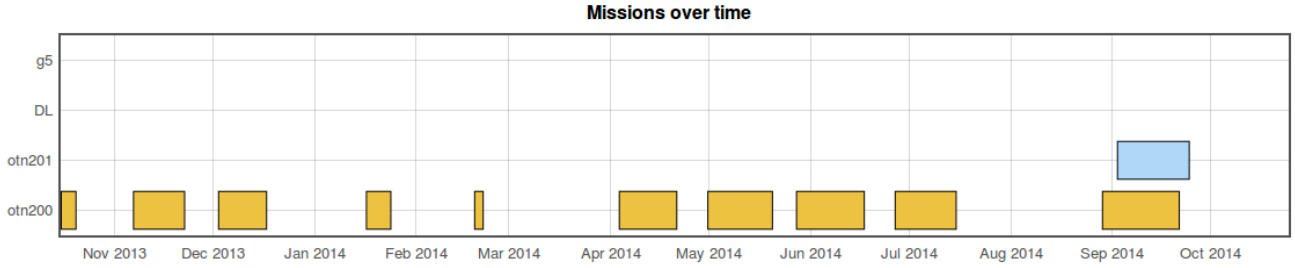

Figure 2. Gantt chart of glider missions for the reporting period. OTN200 and OTN201 are the two G2 slocum gliders owned and operated by OTN.

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 2013 science plan for Gliderpalooza involved 16 Slocum gliders from 12 institutions being deployed simultaneously from Georgia to Nova Scotia, providing a near-simultaneous assessment of water conditions prior to the hurricane season. For this reporting period OTN deployed a glider briefly in Roseway Basin. 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. For this effort OTN deployed two glider is September 2014, one in Roseway Basin and the other on the Halifax Line. Data from all institutions is coordianted through MARACOOS and publicly available.

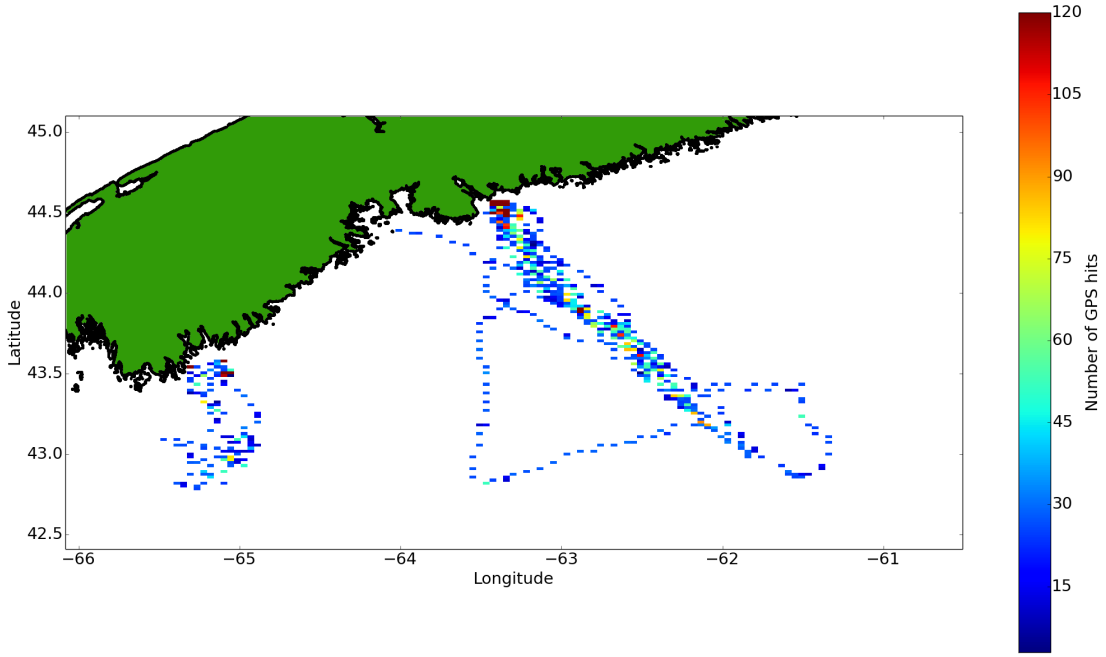

Figure 3. Heat map of glider satellite connections for the reporting period

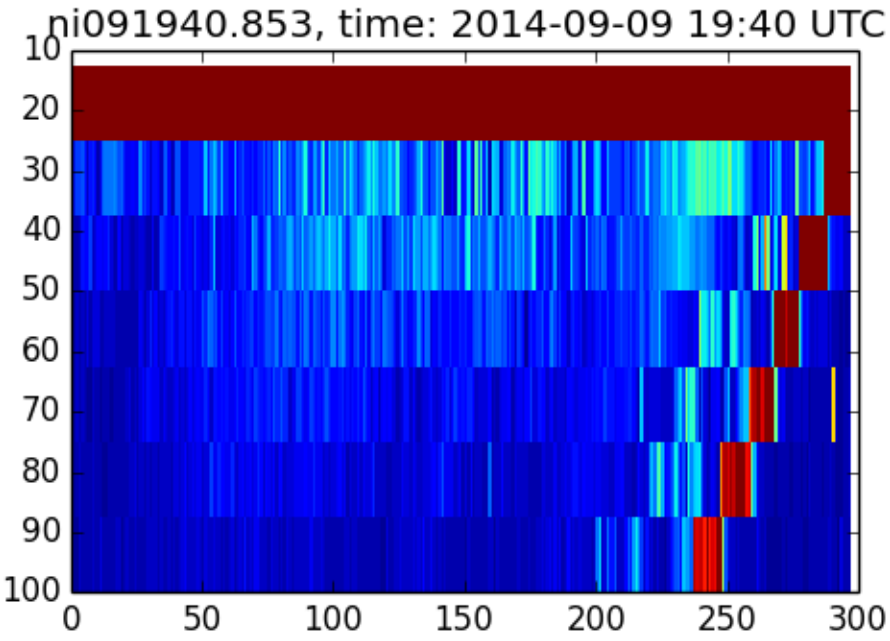

Figure 4. Acoustic returns from the 300 kHz echosounder equipped OTN glider in Roseway Basin, from 19:40 UTC on Sept 9, 2014. The x-axis shows the ping count (the echosounder pinged every 4 seconds) and the y-axis shows the range in meters beneath the glider. Just before ping 250, the glider observed a return from the seabed (at 100-m range; i.e. the glider was 100 m off the bottom) and as it continued its dive, the seabed return was observed at closer and closer ranges until the end of the dive.

The endangered North Atlantic right whale is known to congregate and feed on copepods in diapause deep in Roseway Basin. A 300kHz Imagenex echosounder was installed in OTN201 during the winter/spring of the reporting period to obtain estimates of copepod density. After the glider was returned to OTN by Webb personnel, Dr. Ross' lab calibrated the echosounder in the Dalhousie Aquatron tower tank using tungsten carbide spheres so that absolute volume scattering strengths and hence copepod concentrations could be estimated from the returns. This was done just before the September 2014 mission in Roseway Basin and preliminary data are shown in Figure 4. Figure 4 shows one of the few dives where the acoustic data appear to show the expected copepod near-bottom scattering layer (the cyan line about 20 meters above the red bottom returns). This Roseway Basin OTN glider mission was successfully coordinated with, and MOST deployed, a Woods Hole Oceanographic Institution ocean glider equipped with a DMON (Digital acoustic MONitoring device) that could detect and classify whale calls. The DMON glider detected very few right whales, as did a ship-based survey during the latter part of the mission, which is consistent with the absence of the near bottom scattering layer (which is thought to be the right whales' primary food source in Roseway Basin).

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 Roseway Basin observations are still very preliminary, but they will help locate the feeding and occupancy hotspots for right whales on the Scotian Shelf. 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 an extensive dataset containing the physical, chemical and biological variables necessary to describe an abandonment period. This will be compared with last year's observations (not an abandonment year) to determine the cause.

The wave glider proved itself by uploading >70 bottom-mounted receivers along the Halifax Line. It would have uploaded more, except high seas caused the tow fish cable to experience electrical problems. Being able to upload receivers using a robot will save OTN money in the future.

7. Difficulties encountered

☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)
☒ Personnel problems

There were a few equipment problems. They are listed below:

1) During the deployment of OTN200 in Roseway Basin during Oct 2013 we noticed an increase in the signal from the 880nm backscattering channel. Past experience has taught us that this is indicative of a possible leak from one of the WET Labs ECO-pucks. That mission was aborted and the science bay was sent to Webb for replacement of the leaking units at no cost to OTN.

2) The cable connecting the tow fish to the wave glider suffered electrical breakages during the November 2013 upload of the Halifax Line receivers due to high seas. The cable and mount were both redesigned and replaced by Liquid Robotics at no cost to OTN.

3) The wave glider had a difficult time maintaining sufficient power levels during the November 2013 deployment. Part of that was due to a miscommunication between OTN and Liquid Robotics concerning sensor duty cycles and part due to an oversight by Liquid Robotics when they left the weather station operating for an extended period of time. We established better

lines of communication with Liquid Robotics and installed more efficient solar panels on the glider.

4) OTN200 did not connect on schedule during a mission off Halifax in Feb 2014. This always causes concerns. When the glider was recovered it was discovered that the altimeter had failed, causing the glider to lie on the bottom and not surface as expected. After much trouble shooting the altimeter was replaced.

5) The installation of the Imagenex 300kHz echosounder took much longer than anticipated. This tied up one glider and required us to run our second glider beyond the recommended number of inflections. Apparently integration of the unit ran into significant problems. The unit was finally delivered and the glider with the echosounder has run two missions in Roseway Basin.

6) During the inaugural mission of the new echosounder, full-resolution data were not stored on the echosounder as expected. The echosounder apparently cannot store more than 512 files, after which it simply overwrites the same file continuously. Webb was able to recreate the software glitch. For the next mission the echosounder was put into a different operating mode that stores the full-resolution data on the glider instead.

In April 2014 Jon Pye left the glider group to go work in OTN headquarters. Mr. Pye was with the glider group from the beginning as our information technology specialist and had set up most of our data processing procedures. The search for a suitable replacement, while ultimately successful, took 2 months, delaying some data management decisions.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

The ocean-observing group works closely with the animal tagging and modeling communities of OTN. Last November we deployed the wave glider to upload the receivers along the Halifax Line. The detection data were turned over to the OTN Data Centre. Glider data are supplied to Laura Bianucci and Catherine Brennan of Katja Fennel's group. We regularly consult with Kyoko Ohashi and Shiliang Shan of Jinyu Sheng's group to obtain current estimates for wave glider deployments as well as supply data for current model validation. In particular Mathieu provides processed data sets to feed Shiliang's nested models of the inner Scotian Shelf currents. In turn Mathieu uses Shiliang's model to conduct process studies on specific coastal features of interest. The glider group, in conjunction with Damian Lidgard, validates seal tag irradiance data in support of Katja Fennel's efforts to use seal tags to estimate chlorophyll concentrations. VEMCO VMTs are always deployed on the slocum gliders while the wave glider tows a VEMCO VM4, with all detection data reported to the OTN Data Centre. Personnel for the glider group provide field and logistic support to OTN HQ operations when requested.

b) Interaction/Outreach to Broader Community

The OTN glider group members are rapidly becoming the premier glider operators in Canada, and their expertise is sought out by others within the community. In the past our group has prepped and deployed a 1000m glider belonging to Dr. Jaime Palter of McGill University. More recently, in June 2014, we helped prepare three (3) gliders belong to Memorial University for deployment in the Labrador Sea aboard the CCGS Hudson. Our group was selected by Dr. Stephanie Waterman of the University of

British Columbia and the Bedford Institute of Oceanography to fly gliders as part of an ESRF proposal to study the environment surrounding new oil leases in SW Nova Scotia. Unfortunately that proposal was not funded. A proposal that was funded was the Whale Habitat and Listening Experiment, a MEOPAR funded project to use gliders to locate right whales and describe their environment and will be heavily supported by the OTN glider group.

Mathieu Dever collaborates internationally with John Kocik and Carrie Byron in the US. The objective of this collaboration is to associate John's tagging effort to Mathieu's oceanographic work in the region and to Carrie's modeling efforts on migration of Atlantic salmon.

The glider group met with other glider operators from across Canada during a MEOPAR-sponsored workshop in Montreal in March 2014. The workshop allowed the different groups to compare procedures and best practices but, most significantly, allowed for the creation of Ocean Gliders Canada, a pan-Canadian organization designed to maximize resources and interaction for more effective glider operations.

Richard Davis of the glider group attended the Oceans14 conference in St. John's, NL, to meet with other operators and vendors. During the conference he had a very productive meeting with representatives from Webb about upgrades to MEOPAR gliders.

Finally, personnel from the glider group provide logistics and support to various research efforts at Dalhousie University. For example we helped Julie LaRoche's group during their participation in Ocean Sampling Day in June 2014. Ocean Sampling Day was an international effort to sample as many locations as possible in one day to emphasize the need for cooperation to effectively sample the vast ocean.

The OTN glider group provided support for the MEOPAR WHaLE project late August – October 2014. Not only are data from the OTN glider launched in Roseway Basin integral to the WHaLE project, but the OTN glider group also deployed and recovered WHOI's DMON glider.

Both OTN ocean gliders participated in the Gliderpalooza initiative organized by Rutgers University (an international collaboration to enhance ecosystem monitoring on the eastern seaboard of the United States and Canada discussed in Section 6.b).

Discussions took place with each of the local acoustics companies, Akoostix, JASCO, and Ocean Sonics about coordinating acoustic and glider data and future integration of new acoustic sensors on the gliders.

9. Dissemination of information and results

a) Refereed journal articles (0 total) – accepted/published

b) Refereed journal articles (1 total) – submitted

Dever, M., Hebert, D., Greenan, B., Sheng, J., and Smith, P. (2014) Dynamics of the Nova Scotia Current and its Relationship with Atlantic Salmon Migration Patterns over the Inner Scotian Shelf. Atmosphere and Ocean (submitted).

c) Conference presentations (0 total) – invited

d) Conference presentations (3 total) – contributed

Beck, M., Comeau, A., Davis, R., Pye, J., and Cullen, J. J. (2014) Increasing the accuracy of autonomous, fluorescence-based estimate of Chlorophyll-a: a bio-optical approach. Ocean Sciences Meeting, Honolulu, Feb 2014.

Dever, M., Kocik, J., Zydlewski, J., Hebert, D., and Greenan, B. (2014) Linkage between coastal conditions and migration of Atlantic Salmon smolts along the Halifax Line. American Fisheries Society annual meeting, Quebec City (Aug 2014).

Dever, M., Drinkwater, K., Skagseth, Ø., Sundby, S., and Hebert, D. (2014) Improved method to characterize coastally-trapped, buoyancy-driven currents: A comparison between the Norwegian Coastal Current and the Nova Scotia Current. Ocean Sciences Meeting, Honolulu, Feb 2014.

10. Other contributions and deliverables

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

Richard Davis was interviewed by CTV during the Doors Open Halifax event (7-8 June 2014) and was able to explain how marine robots enhanced programs such as OTN.

Kim Davies was interviewed by CBC radio in August 2014, shortly after the announcement for the funding of the Whale Habitat and Listening Experiment (WHaLE). During the interview she ably described OTN's slocum gliders and their role in the new project.

The glider group provided logistic support to the Rick Mercer Report as they filmed a segment on OTN's shark tagging efforts (Aug 2013).

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

The wave glider was displayed in an event sponsored by the Discovery Centre and designed to attract young people to ocean science (April 2014).

Several personnel for the glider group displayed a Webb slocum glider and a Liquid Robotics wave glider to the general public as part of Doors Open Halifax 2014 (7-8 June 2014). Public interest was high.

c) Invited or contributed presentation/contribution at a workshop

Bianucci, L., Fennel, K., Brennan, K., and Blanchard, H. (2014) Resilience or vulnerability? Oxygen thresholds of marine animals on the Scotian Shelf in the context of environmental change. OTN Symposium, Ottawa, June 3-5, 2014.

Comeau, A., Conrad, K., Pye, J., Covey, B., Davis, R., and Ross, T. (2014) OTN and Marine Robotics. OTN Symposium, Ottawa, June 3-5, 2014.

Davis, R., Comeau, A., Pye, J., Hebert, D., and Ross, T. (2014) Glider operations by Ocean Tracking Network at Dalhousie University. MEOPAR Workshop, MEOPAR Data Management and Glider Operations Workshop, Montreal, March 2014.

Davies, K., Duffus, D., Ross, T., and Taggart, C. (2014) Whale Habitat and Listening Experiment. MEOPAR New Project Orientation Workshop, Montreal, August 2014.

Dever, M., Kocik, J., and Hebert, D. (2014) Biophysical interactions between Atlantic salmon and coastal conditions along the Halifax Line. OTN Symposium, Ottawa, June 3-5, 2014.

e) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, and/or Glider runs, as well as a contribution to a larger piece of work in any of the former

Several glider runs during the reporting period, missions 26 – 36, totalling >4000km traveled. Detailed information about the missions is available on the glider website: gliders.oceantrack.org.

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

Real-time glider data is reported the World Meteorological Organization's Global Telecommunication System and is available for all international forecasting organizations.

Glider data from Gliderpalooza missions are reported to MARACOOS.

All glider data are publically available via the glider website: gliders.oceantrack.org

g) Data deposition to OTN Data Centre

Glider data management personnel work closely with OTN HQ. All gliders are equipped with VMTS and detection data are submitted to the Data Centre.

h) Invited or contributed consultation with an agency; public or private

Several glider personnel attended a MEOPAR-sponsored workshop on gliders and data management in Montreal in March 2014.

The glider group was invited to tour DRDC Atlantic as part of a growing collaboration with DRDC. As soon as the legal machinations are over OTN will take a long-term loan on two DRDC gliders.

Several companies have expressed interest in working with OTN and the glider group as a means to develop products, primarily in acoustics. We have had meetings with representatives from Akoostix, Jasco, Ocean Sonics, and VEMCO. In addition Clearwater Foods met with OTN and IORE to explore how marine robotics can aid in marine resource exploitation.

During Doors Open Halifax Richard Davis had a long conversation with an operations officer from the Canadian Navy about risk mitigation for the wave glider.

k) Internet publishing, portal, blog, electronic publications

One of the primary places for information about the OTN ocean observation program is the glider website: gliders.oceantrack.org.

Information about Gliderpalooza assets, including the OTN gliders, can be found at: www.gliderpalooza.com; while blog posts by OTN and other participants in Gliderpalooza can be found on the MARACOOS website: maracoos.org/blogs/main/.

The ocean observation group has joined the 21st century and now tweets about activities and discoveries at @OTNFieldOps and at @meoparwhale.

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

The ocean observation group and other members of OTN met with MP Peter Stoffer to discuss our activities and what the federal government could to enhance them.

Presentation of OTN ocean observation activities by Adam Comeau and Mathieu Dever to NS Fisheries Minister Keith Colwell (May 2014)

Mathieu Dever helped with both Dalhousie's and OTN's booth at the Ocean Sciences Meeting and at the American Fisheries Society annual meeting. Mathieu helped promoting OTN and the opportunities it provides to students and other researchers in the field.

Richard Davis presented a lecture and gave a tour to the fifth grade class from Armbrae Academy (Jan 2014).

Tetjana Ross gave a lecture to a SuperNova camp ITS for Girls in which new technology, such as marine robots, were discussed. Also, Dr. Ross has discussed the utility of using gliders for projects such as WHaLE in various classes she teaches, including Conversations with Ocean Scientists (OCEA1000) and Environment, Sustainability and Society classes.

Richard Davis participated in SuperNova Ocean Sciences and Technology camp, spending 2h with 18 young campers (Aug 2014).

OTN glider group has hosted multiple groups of visiting scientist though our workshop during the reporting period.

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

A MEOPAR funded project designed to study right whale distribution in order to mitigate ship strikes will use OTN infrastructure, in particular the gliders, as well as OTN expertise. Participation by OTN is critical to the success of this project. OTN will gain a new set of HQP using OTN to address new problems, extra funding to support technical staff in MOST, and the benefit of having new passive acoustic observations for the tracking of whales (the closest you can get to tagging an endangered whale) to compare with the standard OTN oceanographic observations.

o) 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

Matt Beck's algorithm will deliver better estimates of chlorophyll concentration using fluorometers mounted on gliders than the estimates obtained using only the manufacturer's calibration factor.

q) 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

The ocean observation component's continued monitoring of the Scotian Shelf provides useful validation for modern models and baseline data for ocean climate projections.

11. Collaborations with industrial and government partners

a) Partners

The ocean observation group works closely with both industry and government to provide quality data about the waters on the Scotian Shelf. We worked closely with Teledyne Webb Research to have a 300kHz echo sounder installed in one of the two G2 slocum gliders. Ours was only the second glider to have this unit installed and its successful integration required cooperation between TWR and us. After a disappointing mission with the two fish mounted on the Liquid Robotics wave glider we were able to come up with a solution that is being tested as I write. Finally we continue to receive on-going support from the Bedford Institute of Oceanography in the form of both space and vessel time.

b) Contributions

Name of supporting organization: **Teledyne Webb Research**	**Year 5** (2014)
Cash contributions to direct costs of research	0
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	0
2) Donation of equipment, software	0
3) Donation of material	0
4) Field work logistics	0
5) Provision of services	0
6) Other (specify):	0
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	0
2) Salaries of managerial and administrative staff	0
3) Other (specify):	0
Total of all in-kind contributions	0
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Liquid Robotics Inc.**	**Year 5** (2014)
Cash contributions to direct costs of research	0
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	0
2) Donation of equipment, software	0
3) Donation of material	0
4) Field work logistics	0
5) Provision of services	0
6) Other (specify):	0
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	0
2) Salaries of managerial and administrative staff	0
3) Other (specify):	0
Total of all in-kind contributions	0
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Bedford Institute of Oceanography**	**Year 5** (2014)
Cash contributions to direct costs of research	0
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	0
2) Donation of equipment, software	0
3) Donation of material	0
4) Field work logistics	2500
5) Provision of services	0
6) Other (specify):	0
In-kind contributions to indirect costs of research	
1) Use of organization's facilities	15,200
2) Salaries of managerial and administrative staff	0
3) Other (specify):	0
Total of all in-kind contributions	17,700
Is this new funding (acquired during this reporting period)?	no

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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. An Innovacorp Early Stage Commercialization Grant ($20,000) awarded to Broell and Bezanson (held by Taggart) is being used to advance the tags to a market-ready stage in conjunction with securing IP. Broell and Bezanson founded an industrial spin-off company, "Maritime bioLoggers", to make the technology commercially available. Efforts made with using the technology have resulted in an empirical model that relates acceleration to fish size, 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. Tagging effect (tag load) is now being quantified in the laboratory through drag studies in collaboration with the Mechanical Engineering Department at Dalhousie University. Four manuscripts based on the research are becoming well developed at the time of this report.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Franziska Broell	PhD	100	80	May 2010	May 2015
Research Topic: Accelerometery, the key to measuring size-at-age and activity in fish					
Celene Burnell (Hon BSc)	BSc	30	5	May 2013	May 2014
Research Topic: Effect of external tags on behaviour in Atlantic Cod					
Tyler Reyno	BEng	10	2	6 May 2013	30 Apr 2015
Research Topic: Determination of accelerometer tag drag on fishes (Engineering design project)					
Zachary Burns-Grady	BEng	10	2	6 May 2013	30 Apr 2015
Research Topic: Determination of accelerometer tag drag (Engineering design project)					
Jonas Skaalum	BEng	10	2	6 May 2013	30 Apr 2015
Research Topic: Determination of accelerometer tag drag (Engineering design project)					
Greg Winsor	BEng	10	2	6 May 2013	30 Apr 2015
Research Topic: Determination of accelerometer tag drag (Engineering design project)					

b) Role, activities, and opportunities for training

F Broell and A Bezanson (PhD candidate, Biomedical Engineering, Dalhousie University, supported by OTN in 2011-2013) have developed a high-frequency accelerometer tags. The tag designs led to a commercial spin-off through Maritime bioLoggers, a new company spearheaded by Broell and Bezanson. Maritime bioLoggers has already made nationally and international sales. Broell and Bezanson are currently developing an inertial sensor with R&D facilitated by the Early Stage Commercialization Fund ($20,000 Innovacorp) awareded in 2014. These funds will also be used to secure IP around the technology. Broell also enhanced her advisory acumen through advising Celene Burnelle, BSc Honours Student, researching the effects of accelerometer tagging (infection reduction behaviour in response to paraiste and (or) tag load) on Atlantic cod by using signal processing techniques. The results from Burnelle's thesis work are being revised by Broell and will be summarized in a manuscript by spring 2015. Starting in May, we began supervising a 4th year engineering design project with four BEng students in Mechanical Engineering, Dalhousie. This comprehensive 2-term project is focussed on measuring the drag and lift of external tags prodcued by Maritme bioLoggers with the aim of improving the tag load experienced by the fish.

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 will be on sturgeon, salmon, and grey seals and secondarily on cod and other species (e.g. Arctic char) through collaboration with other OTN researchers.

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) enhance the accelerometer tag design to a point where commercial spin-off is possible 2) develop an empirical model from multiple free-swimming trials (Aquatron pool tank) on various sizes of pollock conducted in 2012 to define acceleration metrics that scale with size, 3) determine the effect on behaviour and stress response to external tagging using accelerometer sensors in captivity (Atlantic cod) 4) analyze data from deployments of shortnose sturgeon in collaboration with Matthew 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 (5) deploy accelerometer sensors in collaboration with Damian Lidgard (Dalhousie) to measure feeding behaviour (June – December 2014)

(1) Enhance the accelerometer tag design (Fig. 1): To date, we developed a light-weight, high-frequency micro-accelerometer data logger that not only can record acceleration at high sampling rates, but is also very cost-effective (25% of the cost of comparable tags). This technology is being commercialized by Maritime bioLoggers founded by Broell and Bezanson (www.maritimebiologgers.com). This tag has been sold nationally and internationally (~$20,000). Broell and Bezanson raised venture capital funds through the Early Stage Commerciazliation grant (Innovacorp, $20,000) to further develop an inertial sensor (acceleration, gyroscope, compass) and secure IP around this product. The applications for such a tag would reach from aquatic through to terrestrial and medical, and markets would span the private (e.g., aquaculture) to public (govermental agencies) sectors.

(2) Broell used data from multiple free-swimming trials (Aquatron pool tank, Fig. 1) with pollock (Pollachius virens) 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. This model has the potential to be used to measure size-at-age (growth rate) in the field. A manuscript is currently being developed and to be completed by winter 2014. Maritime bioLoggers is currently developing the incorporated of the relevant software into their accelerometer sensor for on-board processing to deliver estimates of growth rate in tagged fish.

(3) Broell and Burnell used data from free-swimming trials (Aquatron pool tank, Fig. 1) with Atlantic cod to investigate stress and behavioural response resulting from external accelerometer tagging through analysing variations in acceleration records that reflect aberrant behaviour from acceleration records. The results show that behavioural response is consistent over tags of different sizes, however, energy expenditure resulting from tagging is higher in animal tagged with larger tags. Not only gives this insights into tagging effect, 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.

(4) In collaboration with Matthew Litvak and Andrew 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 cm - 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 (~0.1m/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.

(5) A collaboration effort with Damian Lidgard (Dalhousie), Maritime bioLoggers and Broell are investigating the use of high-frequency accelerometers to measure feeding behaviour in seals on Sable Island (June – December 2014). Accelometer tags were attached to two male seals on Sable Island in June 2014 with the aim 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). The data to be used for analyses are expected to be obtained in December 2014.

(6) We have begun, along with Martime bioLoggers to work with 4th year Mechanical Engineering students at Dalhousie (see HQP) to determine the added drag and lift of the external tags as well as optimize tag design to reduce drag. The aim is to develop a model that can be used in estimating the drag of various sizes of tags on various sizes of fish. This should be completed by April 2015.

(7) Five manuscripts and one Patent Application are becoming well developed and we anticipate all submitted/published in 2015 all with Broell (HQP) as lead author. We are confident we can reach these goals as Taggart has dedicated time for working with Broell on these manuscripts as part of his approved sabbatical activities (January through July 2015).

1. Title: Signal processing (proprietary); Patent Application underway. Authors: Broell & Bezanson. Target: USA (Canada) Patent Office. Time-line: submission in January 2015. Innovacorp is involved in the process.

2. Title: Using accelerometers to scale tail-beat frequency and mass in saithe and shortnose sturgeon. Authors: Broell & Taggart. Target: PLOSone as similar (though no fish) have been published here. Time-line: submission in January 2015. All data are in hand, all analyses complete, ms is fully developed. Insights from this paper will be among the first of their kind.

3. Title: Tag and release effects on shortnose sturgeon in their natural environment. Broell et al.; Target: uncertain at this time. Time-line: submission in March 2015. Data are complete, analyses are underway, and outline is completed.

4. Title: Using accelerometers to assess tagging effects on behaviour and energy expenditure in Atlantic cod. Authors: Broell et al. Target: Biotelemetry (or other similar). Time-line: submission in May 2015; data, analyses, results and draft ms are completed.

5. Title: Size-at-age as a function of the growing-degree-day in the phylum Mollusca. Authors: Broell & Taggart. Target: CJFAS as that is where the first paper of this kind (Neuheimer & Taggart, 2010) was published (87 citations). Time-line: submission in July 2015. Data are in-hand and analyses are underway.

6. Title: Tag drag, lift and load as a function of fish size and tag size and design. Authors: Broell et al. Target: Ecological Methods as similar papers published here. Time-line: Submission in Sept 2015. Experiments are underway and data will be in hand no later than March 2015. The insights from this paper will be among the first of their kind.

c) Significant deviations

A previous goal in the project was to publish a manuscript on the new tag technology and application, entitled Bezanson AB, Bröll, F, Taggart, CT: "Light-weight, low-cost acceleration data-logger for monitoring animal movement". The manuscript details the design and fabrication of the low cost

acceleration data-logger for monitoring the activity of aquatic wildlife. However, since publication would reveal trade secrets associated with MaritimebioLoggers, it would prevent securing the IP around the technology. Thus, we decided to refrain from publishing to the benefit of securing IP that is more valuable as it represents a significant advancement for Maritime bioLoggers.

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 Litvak et al. (Mount Allison), Maritime bioLoggers in Halifax, Desert Star Systems in California, USA as well as Aquatron personnel, including the University Veterinary. 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.

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 (Virginia, USA) customers with a revenue of $ 20,000. Further research and development will revolve around developing a market-ready inertial senesor with funding for this R&D through Inovacorp Early Stage Venture Capital (ESCF awarded in 2014).

7. Difficulties encountered

☒ No problems occurred during the reporting period

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 (Mount Allison), Stokesbury (Acadia) and Lidgard (Dalhousie). 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 10 different researchers/agencies around the world.

9. Dissemination of information and results

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

Duff, J., Dean, H., Gazit, T., Taggart, C. T., and Cavanaugh, J. H. (2013) On the right way to right whale protections in the Gulf of Maine - Case study. Journal of International Wildlife Law and Policy. 16: 229-265.

b) Refereed journal articles (0 total) – submitted

c) Conference presentations (1 total) – invited

Broell, F., Bezanson, A., Litvak, M., Taylor, A., and Taggart, C. T. (2014) Challenges of animal activity recognition using tri-axial accelerometers. American Fisheries Society Symposium, Quebec City (ORAL).

d) Conference presentations (5 total) – contributed

Burnell, C., Broell, F., Taggart, C. T., and Dowd, M. (2014) Using external accelerometer tags to identify aberrant behaviour in Atlantic cod. Conference for Dalhousie Oceanography Graduate Students, Halifax, Canada 2014 (ORAL).

Burnell, C., Broell, F., Taggart, C. T., and Dowd, M. (2014) Using external accelerometer tags to identify scouring behaviour in Atlantic cod. Science Atlantic, Halifax, Canada 2014 (ORAL).

Broell, F., Burnell, C., and Taggart, C. T. (2014) Using Accelerometer tags to estimate post-tagging behaviour and stress response in fish in captivity and in the wild. OTN Symposium, Ottawa, Canada 2014 (ORAL).

Broell, F., Burnell, C., Bezanson., A., and Taggart, C. T. (2014) Using Accelerometer tags to estimate post-tagging behaviour and stress response in fish in captivity and in the wild. International Congress on the Biology of Fish, Edinburgh, Scotland 2014 (ORAL).

Broell, F., Taggart, C. T., Taylor, A., and Litvak, M. (2014) Using High-frequency accelerometers to resolve fish activity and behavior in response to environmental variation. 5th Biologging Science Symposium, Strasbourg, France 2014 (POSTER).

10. Other contributions and deliverables

c) Invited or contributed presentation/contribution at a workshop

Broell, F. (Maritime bioLoggers). 2014. An Ocean of Opportunity: Mutual goals, shared resources, effective outcome, Ottawa, Canada, 2014 (invited).

Broell, F. (Maritime bioLoggers). 2014. Panel discussion on 'Developing the Marine Tech and Services Industry - a perspective from a ocean tech start-up' Oceans'14 (IEEE/MTS), St. John's, Canada 2014 (invited).

Broell, F., and Taggart, C. T. (2014) A new scaling relationship between size and acceleration in fish. Workshop: About Biologging, 5th Biologging Science Symposium, Strasbourg, France 2014 (invited).

k) Internet publishing, portal, blog, electronic publications

A summary of Broell's American Fisheries Society meeting presentation (see above) will be published in the Fisheries Information and Technology newsletter.

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

Broell, F., Taggart, C. T., Taylor. A., and Litvak, M. (2014) A novel attachment technique for a rigid mount of Pop-up Satellite Tags. Desert Start Monthly Newsletter.

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

Inovacorp Early Stage Venture Capital competitions (Early Stage Commercialization Fund, $20,000) to further devlop and enhance an inertial sensor.

MEOPAR-WHaLE - see n) below.

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

With a great deal of support from OTN and many others, our MEOPAR WHaLE (Whales, Habitat and Listening Experiment) proposal was fully funded and the research is now getting underway. By working with MEOPAR's observation core and OTN's glider programme we will expand the utility and capability of the gliders by equipping them with passive acoustic monitoring (PAM) systems and at least one high-frequency echosounder one echosounder, and use the acoustic-equipped gliders in conjunction with vessel Automatic Identification System (AIS) data, an array of seafloor mounted PAM platforms and partner-funded ship-board surveys to fill knowledge gaps in the distribution of large whales and their known and suspected habitats in locations on the east and west coasts of Canada where vessel traffic density is high and anticipated to increase, and where in coastal communities ecotourism and private recreation present small-vessel risk to whales. In essence, the whale sounds act as pseudo acoustic tags that the PAM systems recognise. We will also be working with our international partners and use the glider-mounted PAM information to develop, test and implement in Canada the Whale Alert system, whereby areas of concentrated and classified whale vocalizations are made available to mobile device users and can also be transmitted to vessels via an AIS-message.

o) 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

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 and therefore growth and to detect and identify various activities (feeding, escape, passive

movements, tag stress etc.). Maritime bioLoggers aims to incorporate these algorithms into on-board processing of the current technology.

p) 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) 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.

q) 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 cirtical 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 commercially available through Maritime bioLoggers (www.maritimebiologgers.com). To date, national and interantional sales total is close to $20,000. Broell and Bezanson have been awarded $20,000 from Innovacorp to achieve market readiness with their inertial sensor prototype and to assess the commercial potential of intellectual property.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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), Jinyu Sheng (Dalhousie U)

Other OTN Canada participants: S. Cooke, S. Hinch, I. Fleming, C. Taggart

Collaborators: Shelley Deny (UINR), Alex Levy (DFO – Atlantic), Don MacLean (NS-DFA), Dave Patterson (DFO – Pacific), Charles Thompson (MRWS), Fred Whoriskey (OTN), Dale Webber (Vemco)

4. Public summary of report

To date, the research in the Bras d'Or estuary has focused only on the smolt migration stage of Atlantic salmon from the Middle River. At the time that this summary was written, we had not yet begun tagging adult salmon to address the aims of this stage of the research: as originally proposed, capture and tagging of adult salmon in the Middle and Baddeck rivers is set to occur in November (2014). Planning for this project has been ongoing, and significant progress was made at a workshop held by project personnel with provincial, federal, and First Nations partners held in August 2014 in Cape Breton. From this meeting, agreements between all participants were reached on how best to achieve the project's goals, and a suite of best practices for salmon handling and tagging was developed. Field work began in August with the servicing of the entire Bras d'Or Acousitic Array of 26 acoustic receivers, followed by testing of the detection efficiency in the major channels of the estuary. As a result, the array is being extended with another 14 receivers, some of which have been placed in the Middle and Baddeck rivers where adult salmon will be released. Tagging and tracking in the rivers and estuary will begin in November, due to the very late breeding schedule of Atlantic salmon in Cape Breton, which typically spawn around December each year. This study will provide new information about the time-course and extent of seaward migration, as well as its physiological correlates, in post-spawning Atlantic salmon populations native to the Bras d'Or ecosystem of Cape Breton, Nova Scotia. This is important information as Cape Breton populations of Atlantic salmon are listed as endangered (COSEWIC 2010), so knowledge of movement and residency patterns will facilitate basin-wide management activities in the Bras d'Or UNESCO reserve. Physiological biotelemetry is a central tool in conservation biology, and to the emergent field of conservation physiology. By examining individual variation in post-reproductive condition and stress responsiveness, and linking these to environmental conditions encountered, we will examine mechanisms underlying variation in the timing of seaward migration, as well as the mortality of salmon in the Bras d'Or Lakes. By so doing we will also identify the pros and cons of Bras d'Or residency versus migration and ocean residency.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Xavier Bordeleau	MSc	100	70	1 Sept 2014	Dec 2016
Research Topic: Physiological and environmental correlates of habitat use by adult Atlantic salmon in the Bras d'Or Lakes, Nova Scotia					
Alicia Penney	BSc (Hons)	50	25		
Research Topic: Tagging, tracking and data analyses of Atlantic salmon smolt from the Middle River, Cape Breton					

b) Role, activities, and opportunities for training

This project forms the core of Xavier Bordeleau's MSc thesis research. He will be responsible for the tagging and monitoring of all salmon, and is currently being trained in surgical techniques, acoustic telemetry methodologies, and physiological bio-sampling. Alicia Penney has graduated and is preparing for graduate school. She will assist with the operation of the array and collection of oceanographic data.

6. Progress towards objectives/milestones

a) Overall objectives

We have two main objectives/questions: 1) To what extent do Bras d'Or Atlantic salmon utilize local estuarine versus open-ocean migration strategies? We will test the hypothesis that adult 1SW Atlantic salmon espouse a local over-winter migration strategy within the Bras d'Or estuary, whereas 2SW fish will show longer-distance migrations out of the estuary into the North Atlantic Ocean. 2) If Bras d'Or salmon populations have a split distribution of post-spawning migration strategies, what are the physiological pros and cons of these strategies with respect to future survival? Environmental data from Bras d'Or rivers and estuary will be used to explore relationships with migration strategies and their outcomes. These results will be related to the migration patterns of salmon smolts from the same rivers.

b) Progress

We started the year with a Bras d'Or Array data analysis workshop held at CBU in March. Key members of the OTN data management team led the workshop, which was attended by local collaborators as well. The estimates of detection efficiency for the Bras d'Or Array were refined, and revised strategies for range testing were developed.

This summer and autumn we interrogated and serviced the entire acoustic array. All of the receivers were still recording, as long as 18 months after the previous service. However, we have lost one of the receivers (likely due to a scallop dragger). This receiver was replaced with our last spare in October, so the array is back to full strength and ready for the 58% expansion required to cover the adult salmon tagging that starts in November (2014). The data from the download have since been supplied to the OTN data compilation. The results of the download are of particular interest, as we recorded the very first detections of "foreign" tags ever recorded in the Bras d'Or. We suspect that these are Striped Bass tagged in the Mira River, but have yet to confirm this.

B.Sc. student Alica Penney has completed all of the smolt data analyses, including swimming speeds and environmental correlations. We see clear examples of predation inferred from swimming speeds between gates that would be impossible for a salmon smolt: we suspect seals, as the trail ends at St. Paul's Island. All of these data and results have been analyzed, and G. Crossin is preparing a manuscript

for a special issue of Ecological Applications, which will be submitted in 2015. In addition, we have already presented the results to date at three meetings (one scientific and two community), and published a documentary report in a local conservation journal.

Thus far we are still in the planning stage of the adult tagging research. The Middle River population of salmon that we will focus our efforts on began spawning late this year, in November. We are aiming to tag post-spawning fish (i.e. kelts) from late November 2014 through until January 2015. In preparation, Xavier Bordeleau was identified as an excellent candidate for this project's graduate student. He began in G. Crossin's lab at Dalhouise in September 2014. He is responsible for the tagging and subsequent monitoring of all salmon, and is currently being trained in surgical techniques, acoustic telemetry methodologies, and physiological bio-sampling. Together with Fred Whoriskey (OTN), and Dalhousie veterinarians (Chris Harvey-Clark and Purnima Narayanan, Dal Animal Ethics Department) we held a 1-day surgical procedures workshop at the Nova Scotia Governmnet's MgGowan Lake Fish Hatchery.

In August 2014, we held a workshop with project collaborators in Cape Breton, with the specific aim of planning for the year 1 tagging work (Nov 2014). Participants included F. Whoriskey (OTN) as well as other academic (B. Hatcher and Michael Orr, Cape Breton Univeristy), federal (Alex Levy, Greg Stevens, Fisheries and Oceans Canada), provincial (Sean Neary, NS Department of Fisheries and Aquaculutre), First Nations (Shelley Denney, Unima'ki Institute for Natrual Resources), and private foundations (Chuck Thompson, Middle River Watershed Society).

Currently, we are focused on getting the array expansion implemented prior to the release of the adult hatchery salmon, and will be at sea in November 2014 doing the array work.

**B. Hatcher, CBU (other funding sources)*

In late spring we also tagged and released 30 more Atlantic salmon smolts in Middle River (bringing our total tagged sample to 99 fish over three years). The 2014 smolt run was very unusual, as it was two weeks later than ever recorded, and at very irregular intensity. We innovated with a set of dual stage "sleeper" tags that were turned on for 45d, off for 60d, then on again this autumn, to see whether the fish that stayed in the Bras d'Or lakes were still active. A surprising result was that more fish exited through the Great Bras d'Or Channel than through the Little Bras d'Or Channel this year. In the past years, two of every three fish that exited did so through the Little Channel. We have a great deal of detailed oceanographic measurements (CTD, ADCP, IOP) that will be used to try and understand this change in behaviour.

c) Significant deviations

No significant deviations.

e) Scientific and/or engineering significance

As mentioned previously, we do not yet have results as our first field season begins in Nov 2014.

7. Difficulties encountered

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

As previously mentioned with regards to the Bras d'Or acoustic array, we unfortunately lost one of the receivers (likely due to a scallop dragger), but replaced it with our very last spare receiver.

Another difficulty encountered was the relative late start to our adult tagging program. Funds were awarded in January 2014, but due to the late breeding schedule of the Atlantic salmon that we will study, no tagging was possible until November 2014. Consequently, research activity thus far has been limited to array maintenance and range testing, planning sessions, student training and networking both within the OTN and with the community partners.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

13-14 March 2014 – Lenore Bajona convened a Bras d'Or Salmon Tracking Data Workshop with Bruce Hatcher, Michael Orr, Alicia Penney, Martin Leguizamon, Fred Whoriskey, Glenn Crossin, Duncan Bates and Jenyu Li, as well as Mary Kennedy from OBIS and Shelley Denny from UINR.

24 June 2014 - G. Crossin and F. Whoriskey met with Alex Levy and Greg Stevens at DFO-Bedford Institution of Oceanography to discuss logistics around salmon sampling and permitting.

1 August 2014 - G. Crossin and F. Whoriskey met with B. Hatcher who hosted a workshop with project collaborators in Cape Breton, with the specific aim of planning for the year 1 tagging activities (Nov 2014). Other participants included: Michael Orr and Alycia Penny (Cape Breton Univeristy); Alex Levy, Greg Stevens (Fisheries and Oceans Canada, via telephone); Sean Neary and Daryl Murrant, Don MacLean (NS Department of Fisheries and Aquaculutre, via telephone); Shelley Denney (Unima'ki Institute for Natrual Resources); Chuck Thompson (Middle River Watershed Society).

12 September 2014 - G. Crossin, F. Whoriskey, and graduate student Xavier Bordeleau travelled to the McGowan Lake Fish Hatchery in Nova Scotia to conduct a fish surgery workshop. This workshop was done in collaboration with Dr. Chris Harvey-Clark and Purnima Narayanan, who are veterinarians in the Dalhousie Animal Ethics department. Harvey-Clark and Narayanan instructed Bordeleau in basic surgical techniques and best practices for fish care. The Hatchery Manager Mike McNeil welcomed our activities and provided laboratory space and live fish to work with. This workshop was held in preparation for the field season beginning in November 2014.

27 October 2014 - G. Crossin and co-PIs J. Sheng and B. Hatcher (via telephone), Xavier Bordeleau, and Kyoko Ohashi and Shiliang Shan (both in Sheng's lab) met to discuss ways to incorporate the collection of oceanographic data into the project and thus provide a means for examining the environmental correlates of salmon behaviour once field work begins.

b) Interaction/outreach to broader community

This year B. Hatcher and various members of the CBU team provided multiple updates on the status of salmon research in the Bras d'Or Array to the Cape Breton Salmon Initiative (CSI) and the Cape Breton Naturalists Society (CBNS). These meetings include mainly members from outside the OTN, and so serve to build awareness and foster collaboration in the broader community. Key participants included First Nations researchers from the UINR and EFWC, Don MacLean and staff from the NS Dept. of Fisheries & Aquaculture, Lewis Hinks and staff from the Atlantic Salmon Federation, and members of

local Anglers and Conservation associations. One result of these meetings was the contribution of $7k cash funding for VEMCO tags and range testing.

9. Dissemination of information and results

a) Refereed journal articles (0 total) – accepted/published

b) Refereed journal articles (0 total) – submitted

c) Conference presentations (1 total) – invited

Hatcher, B. G. (2014) Tracking the migrations of Atlantic Salmon using acoustic Telemetry. Ocean University of China, Qingdao, 16th October, 2014.

d) Conference presentations (0 total) – contributed

10. Other contributions and deliverables

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

Hatcher, B. G., Denny, S., Crossin, G., Orr, M., Leguizamón, M., Fagan, N., Oldford, D., Penney, A., and Woodland, D. (2014) Tracking Tagged Salmon Smolt in the Bras d'Or Biosphere Reserve. Cape Breton Salmon Initiative, Wagmatcook, N.S. 18 April, 2014.

Hatcher, B. G. (2014) Update on the status of Salmon tracking ion the Bras d'Or estuary. Cape Breton Salmon Initiative, Eskasoni, N.S. 16 September, 2014.

Hatcher, B. G. (2014) Tagged and Tracked: Atlantic Salmon in the Bras d'Or. Cape Breton Naturalists Society. Sydney. 12 November, 2014.

c) Invited or contributed presentation/contribution at a workshop

Penney, A., Hatcher, B. G., Orr, M., and Murray, C. (2014) Tagged Salmon Update. Bras d'Or Salmon Research Workshop, Wagmatcook, N.S. 1 August, 2014.

g) Data deposition to OTN Data Centre

The data downloaded from the receivers were supplied to the OTN data compilation team in November (2014).

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

Hatcher, B. G. (2014) Discovering Secrets of Salmon Swimming within The Bras d'Or Ecosystem. The Blue Heron 18(2):7-9. Bras d'Or Stewardship Society, Baddeck, N.S.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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

During fall 2013, 12 eels were equipped with satellite tags and released off Nova Scotia in an attempt to track them en route to their spawning grounds in the Sargasso Sea. Five eels were tracked during several weeks and beyond the Scotian Shelf, up to 760 km from the coasts, which represents our longest tracked distances at sea and thus brings the first insights into the American eels' trajectories in the open ocean! After a southward direction while over the Scotian Shelf, the eels took a southeastward direction, which was unexpected since it is not the direct route for reaching the spawning grounds. At the same time, 75 silver eels were acoustically tagged and released in the Saint Lawrence maritime estuary. Only ten of these eels were detected at the exit of the Gulf, which represented a similar low detection rate to those of previous years. It nevertheless provided new data about the migration in the Gulf, although some travel ground speeds seemed too high to correspond to eels (predators?). In collaboration with physical oceanographers from Project I.1.2, two biophysical particle-tracking models were developed for simulating the migration of eels from the Saint Lawrence estuary to the Sargasso Sea. These models provided very interesting results and represent valuable tools for testing hypotheses. The model about the migration in the Gulf showed that the tidal transport in the estuary and a compass orientation were necessary to match with the values observed in the field. It also showed a very low probability for eels to cross the Cabot Strait at the northeastern part of it. The model about the migration in the open ocean showed that a true navigation behaviour would lead to migratory paths less favourable compared to two other orientation behaviours. It also allowed us to evualate the energy expenditure and showed that the ocean currents have a significant effect on it. Our field experiments keep going this year (October 2014) using silver eels from the St. Lawrence Estuary equipped with satellite tags and released off Nova Scotia and eels acoustically tagged and released in the maritime estuary, in an attempt to learn more about their migration at sea.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Mélanie Béguer-Pon	RA	100	100	17 Sept 2010	31 Dec 2016
Research Topic: Migratory behaviour of silver American eels					

b) Role, activities, and opportunities for training

Similarly 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 2013 and fall 2014. She also collaborated with physical oceanographers (research OTN team of Theme I.1) in the development of two biophysical particle-tracking models that aimed at clarifying the migratory behaviour of silver eels. Thanks to that collaboration (particle-tracking models but also data matching between data recorded by the tags and physical model outputs), Mélanie developed her programming skills and her understanding of the physical environment in which the eels migrate. In July 2014 Mélanie participated in a state-space modelling workshop organised by OTN in Halifax, learning how to use the R package TMB, which will be useful for further statistical analyses associated with animal movements.

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 grounds (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 clarify/determine the migratory pattern of silver eels (i.e. maturing adults) from their departure in fresh waters to their spawning grounds 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 will acoustically tag and release silver eels during fall 2013 and 2014. The tagging experiment with satellite tags (started in fall 2011) in an attempt to follow eels in the open ocean will continue by equipping and releasing eels off eastern Canada. 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 will 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

Results from the large-scale acoustic tracking conducted during OTN phase I were recently published in two papers; the first is about the movements of yellow eels (Ecology of Freshwater Fish, accepted in early 2014) and the second one is about the migratory pattern of silver eels from the Saint Lawrence River to the exit of the Gulf (Canadian Journal of Fisheries and Aquatic Sciences, accepted in spring 2014). Another paper about the approach involving the otolith analysis to determine the habitat use by yellow eels was recently submitted (October 2014) to the journal Ecology of Freshwater Fish and is presently under review .

Additional information on the migratory behaviour of silver eels from the Saint Lawrence Estuary to the exit of the Gulf (Cabot Strait) were acquired in fall 2013 and 2014 thanks to detections made by the acoustic receivers moored at Cabot Strait and at various locations in the Gulf and also by Grey Seals bioprobe (OTN Project I.2.4). This fall (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. These tags were recently developed by VEMCO and can withstand the great depth (i.e. pressure) at which eels likely swim in the Gulf (up to 500 m). If detected, it will provide new useful information: the temperature will allow us to verify that the tags were in the water while detected (and not in the stomach of homeothermic fishes) and it will inform us of the depth at which eels were when crossing the Cabot Strait. This is data we currently don't possess, but is essential for evaluating the detection efficiency of the acoustic line. The glider equipped with acoustic receivers will probably be deployed in early winter (late November/early December) in an attempt to detect more tagged eels in the vicinity of the Cabot Strait Line. Detections at this location will provide new data that will have to be analysed and compared to previous years. A paper about these data (detections of silver eels in and at the exit of the Gulf of Saint Lawrence) should be prepared next year in collaboration with MFFP and OPG.

In September and October 2013 we equipped 12 eels caught in Nova Scotia (Cape Breton) with satellite tags (10 SeaTag GEO from Desert Star Company and 2 X-tags from Microwave Telemetry that we did not deploy the previous year). Two tags disappeared, we never heard back from them. All remaining satellite tags popped before the programmed date (like previous years) but five of them popped in the open ocean - far away from the coast (up to 750 km for 3 of them!) at unexpected locations. It thus represents a better success than last year - and provides the first insights into eel-trajectories at sea. To go beyond the first transmitting positions (i.e. end of tracking period, presumably where the tag detached itself from the eel), we developed a matlab program for matching the environmental data recorded by the tags with results from physical models (in collaboration with physical oceanographers of Theme I.1). We did that also for the data that were obtained from the satellite experiments conducted in 2011 in the Gulf in order to assess the trajectories before predation and the locations of the predation events.

Very recently (on October 15 and 16, 2014) we released 16 silver eels equipped with satellite tags (15 X-tags and 1 SeaTag GEO that was retrieved from last year's deployment) off Nova Scotia. The field tracking is thus currently under way. The tags were programmed to transmit their data in January and March 2015. According to the difficulties highlighted during our previous experiments (high predation in the Gulf, issues for finding large eels in Nova Scotia, trust issues with data from SeaTag GEO tags associated with a low recording/transmission rate), we decided to go back to the X-tags from Microwave Telemetry Company and to take large eels caught during their downstream

migration in the Saint Lawrence Estuary. These eels were transported by truck to Blandford (Nova Scotia), equipped with the satellite tags and released at that location. It seems that our translocation approach is also the one being adopted by our European colleagues who try to follow European eels en route to their spawning grounds.

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 objectives of the second model (migration in the Open Ocean, offshore and to the Sargasso Sea for both American and European eels) was revised and the accent was placed on assessing the effect of the flow field on the migratory path of eels according to 3 likely behaviours. A total of 336 scenarios by species were simulated. The approach and associated results were presented on several occasions during international and national meetings and were well-received. A paper was written and should be submitted by the end of the year to the Symposium issue of ICES Journal of Marine Sciences that follows the Eel symposium held during the American Fisheries Society Congress during summer 2014. Additional simulations were run using the model about the migration from the Saint Lawrence estuary to the exit of the Gulf. Dr Kyoko Ohashi and Dr Jinyu Sheng, who developed the physical model Dalcoast and the particle-tracking, wrote a technical paper about it and submitted it recently. It allows simplifying the technical description in the paper we are currently preparing about the simulated migration in the Gulf.

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 the project's co-investigators and collaborators. Mélanie moved in September 2013 to Halifax and is currently physically located in the Department of Oceanography, at Dalhousie University, which considerably facilitated the collaboration about the modelling work with physical oceanographers from OTN theme I.1. The field tracking experiment (using satellite tags) also took place in Nova Scotia this year, which allowed Mélanie to visit and evaluate the site and allowed the active participation of the physical oceanographers Shiliang Shan, Kyoko Ohashi and Jinyu Sheng.

Regular communications with the PIs are maintained, mainly by emails but also by virtual conferences. Also 3 events allowed us to meet through the year: the Canadian Eel Science Working Group meeting in December 2013, the OTN meeting in June 2014, and the American Fisheries Conference in August 2014.

e) Scientific and/or engineering significance

Despite the difficulties we encountered during our last satellite tagging experiments (eel size, satellite tag size associated with low capacity storage, low transmission rate and lack of data calibration), we nevertheless obtained interesting results and thus the first insights into the silver eels' trajectories in the open ocean off the continental shelf. Of the 12 eels equipped with satellite tags, two never transmitted to satellites, but five of them first transmitted after 12 to 60 days: two transmitted at 150 and 265 km from the release site (i.e. from the coast, over the Scotian Shelf and at

the edge of it) and three transmitted at ~ 610 to 760 km from the coasts, i.e. beyond the Scotian Shelf. Data from these 5 tracked eels (first transmitting position, as well as infered position from recorded environmental data) indicate that the eels took a southward bearing right after their release, from the coast to the edge of the Scotian Shelf. After that, they moved in a southeastward direction (the 3 furthest tags first transmitted in the same area), but probably not as far east as the first transmitting positions would have led us to believe (the tags may have drifted a couple of days before transmitting), but still not a strictly southward direction (hypothesis tested with the particle-tracking model developed in collaboration with Kyoko Ohashi and Jinyu Sheng) which thus represent unexpected trajectories. It appears unlikely that the silver eels follow the coasts to reach their spawning grounds. They also may not take the more direct route to reach the assumed spawning grounds in the Sargasso Sea. Rather, they may follow the decreasing geomagnetic field intensity gradient. Only one tag (X-tag) was equipped with a depth sensor and that tag did pop up after 10 days and at a distance of 29 km from the release site. That tag showed the eel performed a diel vertical migration immediately after release for 1.5 days and then stayed around 55 m depth (presumably the bottom) for 8 days before the tag reached the surface (the tag was programmed to detach itself after 7 days of constant pressure). The diel vertical behaviour was observed in the Gulf during our previous years experiment and this also seems to occur in the open sea (like for other Anguillid species). Temperature data do not seem to indicate any case of predation by homeothermic fish during the tracking period, encouraging us for releasing eels over the Scotian Shelf instead of the Gulf. Sixteen large eels from the Saint Lawrence River were equipped mid-October 2014 with satellite tags (X-tags) and released off Nova Scotia (off Blandford, NS). We thus hope that the tags will remain attached to the eels until the spawning grounds and the secrets of their spawning migration routes will be revealed!

Of the 75 eels that were acoustically tagged in fall 2013 by our partners from the MFFP and OPG and released in the maritime estuary, 15 were detected by OTN receivers deployed in or at the exit of the Gulf (total of 290 detections). Four were detected by receivers moored in the maritime estuary, at ~150 km from the release site; one eel was detected by a Grey Seal bioprobe nearby the Magdalen Islands and 10 were detected at the Cabot Strait line. The detections in the Gulf, although few, are very useful since little is known about the migration at that location. At the exit of the Gulf - Cabot Strait acoustic line - , only ~13% of the tagged eels that were detected. This low detection rate was similar to previous years (9.8% in 2011 and 5.1% in 2012). As in previous years , the detection rate of wild eels (large silver eels) was almost half that of small silver eels that come from a re-stoking program (eels caught as glass eels in Nova Scotia and stocked in the upper Saint Lawrence River). These observations are very useful for management purpose since they indicate that stocked eels are able to perform their migration from the upper St. Lawrence to the exit of the Gulf (suggesting no imprinting is required for this migration). However, the travel ground speed of some detected eels between the estuary and the Cabot Strait were too high to be realistic. According to simulations made using the particle-tracking model developed with Kyoko Ohashi and Jinyu Sheng, a very high and constant swimming speed (and assuming perfect navigation abilities) would be required to reproduce the observed duration of migration. The simulations need to be done with the 2013 background in order to confirm the results, but it would suggest that the detected tags were not inside eels but inside predators. Furthermore, unlike previous years, half the eels were detected at the northeastern part of the Cabot Strait, very close to Newfoundland which is an area where the main current is an entering one and is thus not favourable for exiting the Gulf (the biophysical particle-tracking showed a very low probability for eels to cross the Strait at that location). This fall (October 2014) 52 eels were equipped with acoustic tags that have temperature sensors. If detected, it will allow us to check our predation hypothesis by homeothermic fishes like porbeagle shark or tuna.

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. The first model, based on the 3-D physical model DalCoast, was built for testing the required behaviours (swimming speeds and orientation abilities) necessary for eels to escape the Gulf within the time window observed from the field experiments (mainly acoustic tracking). The simulations from this model showed that the selective tidal transport in the estuary and a compass orientation behaviour toward the Cabot Strait in the Gulf are required for eels to move out the Gulf within the observed time window. An orientation toward higher salinity and/or greater depth led to a lower success and a large proportion of virtual eels go in the northeastern part of the Gulf instead of exiting it by the south. It also showed that high constant swimming speed values are required for matching with the first detections at Cabot Strait (unrealistic for some, suggesting predation of the tags as mentioned in the previous paragraph). The simulations also showed that the probability for eels to cross the Strait at the northeathern part of it is very low. Furthermore, the diel vertical migration and the compass orientation behaviours play a role in reducing the spread of the group (eels are believed to migrate in schools although this has never been observed at sea).

The second biophysical particle-tracking model simulates the migration of both the American and the European eels to the Sargasso Sea. Three directed swimming behaviours that lead to 3 different pathways were tested and the effect of the flow field on the duration of migration, trajectories and the environmental conditions eels would experience along the way were assessed. Among the main results, we showed that for both species a true navigation behaviour toward the assumed spawning grounds would lead to the less favourable route, i.e. where the currents are the strongest and not in the appropriate direction, relative to a compass orientation behaviours toward the northern limit of the Sargasso Sea or toward the decreasing gradient of geomagnetic field intensity. The success of virtual eels mainly depends on the swimming speed and thus critical swimming speeds were highlighted. The tested range of diel vertical migration (4 depths) has no significant effect on the success but has an impact on the energy expenditure and on the temperature and salinity experienced along the way. The temperature gradient would be too small and sometimes uncertain to be used as a migratory cue. The energy would not be a limiting factor but the oceanic currents generally increase the energy consumption (particularly in the case of true navigation behaviour), showing the importance of models taking into account the oceanic currents for evaluating the required energy (the published laboratory studies all considered a straight distance toward the Sargasso Sea and without the effect of the currents).

7. Difficulties encountered

☒ Scientific problems/difficulties

☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)

As already highlighted in our last year report, the satellite tags (SeaTag GEO, Desert Star Company) used in fall 2013 were significantly longer than the specifications provided by the company. It also appeared that these tags were not well-calibrated (geomagnetic field intensity), the capacity storage and the transmission rate were very low (compared to other satellite tags we used in the past). It was thus very difficult, most of the time impossible, to infer from the data transmitted by these tags accurate positions of eels between the release location and the first transmitting position. Furthermore finding large eels in Nova Scotia is very difficult and we think that the current available satellite tags remain too large for eels from this area. We thus decided to equip large eels from the Saint Lawrence Estuary

(double the body mass of eels living in Nova Scotia) and to translocate them directly for release off the coast of Southwest Nova Scotia (and not releasing them in the Gulf where we now know the predation rate is very important).

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Our collaboration with the physical oceanographers from OTN theme I.1 has been facilitated with the moving of Dr. Mélanie Béguer-Pon in September 2013 to Dalhousie university. Mélanie was then able to work more closely with all participants through numerous informal meetings. As biologists, our main role in this collaboration was to define scenarios and behaviours to be implemented and tested in the models. The physical oceanographers provided the physical input and developed the particle-tracking program that Dr. Béguer-Pon learned to use. Mélanie then analysed the output and took the lead in the writing of papers. Also the physical oceanographers actively participated in this year field experiment providing us extra hands and a great ocassion for them to have a concrete look at our field experiment.

In June 2014, Dr. Mélanie Béguer-Pon and David VanderZwaag (OTN member, lawyer at Dalhousie University) presented together during the CZC conference the natural science, technology and governance aspects of our project. Consequently, we met to prepare for the conference. In addition, we discussed a future collaboration on an American eel and European eel comparison from both scientific and management perspectives. Discussions continued also in October 2014 with the PIs during our field tagging experiment.

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 acoustically tagged silver eels in the Saint Lawrence River in fall 2013 in order to detect them in the Gulf of Saint Lawrence and at Cabot Strait. Their goals regarding the eels are more for management purposes (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 hypotheses about eel behaviours. Detections are shared between all partners and results are discussed by email/phone, but also in person at the occasional meeting (CESWoG, AFS). Based on previous results and on our recommandations, they decided to equip eels this year with acoustic tags equipped with temperature sensors (for testing our predation hypothesis).

We participated in the working group on eel biology (CESWoG) that was held in December 2013 in Ontario, allowing us to contribute to the development of a national plan for eel management. The purpose of these meetings is to share information on the American eel relevant to new and emerging issues in eel science.

9. Dissemination of information and results

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

Béguer-Pon, M., Castonguay, M., Benchetrit, J., Hatin, D., Legault, M., Verreault, G., Mailhot, Y., Tremblay, V., Lefaivre, D., and Dodson, J.J. (2014) Large scale migration patterns of silver American eels from the St. Lawrence River to the Gulf using acoustic telemetry. Canadian Journal of Fisheries and Aquatic Sciences 71: 1-14.

Béguer-Pon, M., Castonguay, M., Benchetrit, J., Hatin, D., Legault, M., Verreault, G., Mailhot, Y., Tremblay, V., and Dodson, J.J. (2014) Large-scale, seasonal habitat use and movements of yellow American eels in the St. Lawrence River revealed by acoustic telemetry. Ecology of Freshwater Fish: 1-13. DOI 10.1111/eff.12129.

Engler-Palma, C., VanderZwaag, D. L., Apostle, R., Castonguay, M., Dodson, J.J., Feltes, E., Norchi, C., and White, R. (2013) Sustaining American eels: A slippery species for science and governance. Journal of International Wildlife Law Policy, 16: 128-169.

b) Refereed journal articles (1 total) – submitted

Benchetrit, J., Béguer-Pon, M., Sirois, P., Castonguay, C., Fitzsimons, J., and Dodson, J.J. Using multi-element otolith line scans to retrace habitat use of American eels Anguilla rostrata in the Saint Lawrence River. Ecology of Freshwater Fish (Submitted).

c) Conference presentations (0 total) – invited

d) Conference presentations (8 total) – contributed

Béguer-Pon, M., Ohashi, K., Katavouta, A., Thompson, K., Dodson, J., and Castonguay, C. (2014) Understanding Silver Eel Migration Behaviour at Sea: Insights from Field and Virtual Tracking. Oral communication at the American Fisheries Society Annual Meeting, August 17-21, Québec, QC, Canada.

Béguer-Pon, M., Ohashi, K., Sheng, J., Dodson, J., and Castonguay, C. (2014) Using a Coupled Bio-Physical Particle Tracking Model to Improve Our Understanding of Eel Behaviour during the Early Phase of the Marine Migration. Oral communication at the American Fisheries Society Annual Meeting, August 17-21, Québec, QC, Canada.

Benchetrit, J., Béguer-Pon, M., Sirois, P., Castonguay, M., Fitzsimons, J.D., and Dodson, J.J. (2014) Habitat Use of American Eels in the Saint Lawrence River Inferred from Multi-Element Otolith Line Scans. Oral communication at the American Fisheries Society Annual Meeting, August 17-21, Québec, QC, Canada.

Shan, S., Béguer-Pon, M., Thompson, K.R., Castonguay, M., Dodson, J., and Sheng, J. (2014) How Do American and European Eels Migrate to the Sargasso Sea? Oral communication at the American Fisheries Society Annual Meeting, August 17-21, Québec, QC, Canada.

Stanley, D., Threader, R., Verreault, G., and Béguer-Pon, M. (2014) Early Results on Marine Migration of Stocked and Transported Eels from the St. Lawrence: Insights from a Large-Scale Acoustic Tracking. Oral communication at the American Fisheries Society Annual Meeting, August 17-21, Québec, QC, Canada.

Béguer-Pon, M., Ohashi, K., Shan, S., Katavouta, K., Castonguay, M., Dodson, J.J., Sheng, J., and Thompson, K. (2014) The challenge of tracking eels during their marine migration. Oral communication at the OTN Annual Meeting, June 2-5, Ottawa, ON, Canada.

Béguer-Pon, M., VanderZwaag, D.L., Dodson, J.J., and Castonguay, M. (2014) Sustaining American Eels: A Slippery Species for Science and Governance. Oral communication at the Coastal Zone Canada 2014, June 15-18.

Béguer-Pon, M., Shan, S., Ohashi, K., Benchetrit, B., Castonguay, M., Verreault, G., Thompson, K., Sheng, J., and Dodson, J.J. (2014) Tracking real and virtual eels to unravel the mystery of their oceanic migration. Oral communication at the 2014 Ocean Sciences Meeting, Honolulu, Hawaii, USA.

10. Other contributions and deliverables

c) Invited or contributed presentation/contribution at a workshop

Béguer-Pon, M., Ohashi, K., Shan, S., Castonguay, M., Thompson, K., Sheng, J., and Dodson, J. (2013) Using coupled biophysical particle-tracking models to clarify the spawning migration of eels. Oral presentation at the annual Canadian eel science working group (CesWog) meeting, December, Cornwall, Ontario, Canada.

Benchetrit, J., Béguer-Pon, M., Castonguay, M., Sirois, P., Fitzsimons, P., and Dodson, J.J. (2013) Using multi-element otolith line scans to retrace habitat use of American eels in the Saint Lawrence River. In Oral presentation at the annual Canadian eel science working group (CesWog) meeting, December, Cornwall, Ontario, Canada, Cornwall, Ontario, Canada.

g) Data deposition to OTN Data Centre

Metadata about the acoustic tagging of 75 eels and the equipement of 12 eels with satellite tags were deposited to OTN Data Centre in fall/winter 2013.

o) 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

Both biophysical particle-tracking models developed in collaboration with physical oceanographers from OTN theme I.1 represent useful tools for testing hypotheses about migrating eels' behaviour in the Gulf and in the Open Ocean. For instance, the model in the Gulf is currently used for assessing the swimming speed required for matching with the fastest eels detected at the exit of the Gulf. It demonstrates (although additional simulations may be run) that the involved values would be too high to be realistic, and therefore, detections of some tags may not correspond to eels, but to predators.

Another example of application would be for management purposes in the case of the stocking program with smaller eels. The duration of migration as well as the energy required can be easily estimated.

11. Collaborations with industrial and government partners

a) Partners

Our partner from the Ministère des Forêts, de la Faune et des Parcs of Québec (MFFP) in collaboration with Ontario Power Generation (OPG) acoustically have tagged silver eels every fall since 2011. They caught them while migrating in the brackish and maritime St. Lawrence Estuary and released them at the same location. They equipped large wild silver eels and stocked silver eels with acoustic tags. The stocked silver eels are much smaller than the wild ones; they were caught as glass eels in Nova Scotia a few years ago and re-stocked in the upper Saint Lawrence for the purpose of stocking program experiments. Our partners are thus interested in the detections made both in and at the exit of the Gulf, in order to establish if the stocked eels are able to migrate like the wild larger ones. They buy the tags, do the tagging and send their metadata directly to OTN database managers or to Dr Mélanie Béguer-Pon who transfers them. We then transmit the detections when the receivers are downloaded, as well as a quick report with maps. They can also assess them directly. These detections provide very useful information about the escapement of eels from the Gulf of Saint Lawrence, which is one the objectives of our project. They also serve for parameterizing our biophysical particle-tracking model which is about the migration in the Gulf. This model can also serve to test hypotheses about some suspicious detections (e.g. high swimming speed values). Dr Mélanie Béguer-Pon participated in a presentation given by David Stanley during the American Fisheries Conference held in August 2014 in Québec. During the summer we, along with our partners, decided to use new acoustic tags equipped with temperature sensors in order to test the hypothesis of predation and to obtain an indication of the swimming depth of eels while crossing the Cabot Strait. A paper gathering the detections made both in and at the exit of the Gulf should be prepared next year in collaboration with all involved partners.

b) Contributions

Name of supporting organization: **DFO**	**Year 5** (2014)
Cash contributions to direct costs of research	$2,000
In-kind contributions to direct costs of research	
7) Salaries for scientific and technical staff	$16,500
8) Donation of equipment, software	
9) Donation of material	
10) Field work logistics	
11) Provision of services	
12) Other (specify):	
In-kind contributions to indirect costs of research	
4) Use of organization's facilities	
5) Salaries of managerial and administrative staff	
6) Other (specify):	
Total of all in-kind contributions	$18,500
Is this new funding (acquired during this reporting period)?	no

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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. Crossin.
Collaborators: Colin Simpfendorfer and Michelle Heupel (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 sturgeon from the mixed stock aggregation that migrates every summer through Minas Basin, Nova Scotia and from the Saint John River, New Brunswick spawning stock with acoustic coded-pingers, conventional tags (Floy), Passive Integrative Transponders, and Pop-up Satellite Archival Tags. A population estimate based on returns from 2013 Minas Basin, Floy tagged sturgeon determined the summer aggregation in Minas Basin during 2014 consisted of ~25,000 individuals. This past year, 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 archival 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 2015**.** We also determined the spatial and depth distribution for the summer aggregation from the Minas Basin and the Saint John spawning stock overwintering in the outer Bay of Fundy in an area offshore of the Saint John Harbour and in the Bay of Fundy at depths of 50-110 m over sandy mud and moraine substrates. During 2014 an Atlantic sturgeon acoustically tagged in Minas Basin was recovered by a OTN grey seal bioprobe on the Scotian Shelf. In the Saint John River, we examined the timing and location of spawning and spawning periodocity. Eleven tagged adults returned for spawning in the Saint John River during 2014 after a minimum of 2 years at large, but many fish have not returned in over 4 years. Of the returning fish, 9 were male suggesting spawning intervals are shorter for males. A total of 22 sturgeon Floy tagged and 21 sturgeon acoustically tagged in Minas Basin have been recaptured in the Saint John commercial fishery or detected by the Saint John acoustic receivers. In 2014, 11 sturgeon acoustically tagged in Minas Basin during 2010-2013 were recovered in the Saint John. We also examined movement and aggregation areas of juvenile Atlantic and shortnose sturgeon in the Saint John River.The Acadia group in collaboration with DFO developed a growth model for the Atlantic sturgeon caught in the Saint John River commercial fishery using pectoral fin spines. Results from our project are currently being used by Canadian and USA government departments for fisheries management and endangered species decisions. Surveys for undescribed populations of sturgeon in

Cape Breton has revealed a previously unknown population of striped bass in the Mira River. A total of 30 bass were acoustically tagged and the over winter site is now known.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Laura Logan-Chesney	MSc	100	75	1 Sept 2012	1 Jun 2015
Research Topic: Population specific movements of Atlantic sturgeon in Minas Basin					
Colin Buhariwalla	MSC	100	20	1 Sept 2012	1 Jun 2015
Research Topic: Habitat Utilization and Movements of Striped Bass in the Mira River, NS					
Jeffrey Beardsall	MSc	100	50	1 Sept 2011	1 Sept 2014
Research Topic: Atlantic Sturgeon seasonal habitat occupancy and survivorship in the Bay of Fundy					
Nathan Stewart	BSc	100	50	1 Sept 2013	1 Sept 2015
Research Topic: Age and Growth of Atlantic Sturgeon from the Saint John River Stock					
Andrew Taylor	Bsc Hons and MSc	100	100	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					
Jeff Bell	BSc	100	100	1 May 2013	1 May 2014
Research Topic: Movement patterns and feeding ecology of Atlantic sturgeon juveniles in the Saint John River, NB					
Matt Brown	BSc	100	100	1 May 2013	1 May 2014
Research Topic: Movement patterns of Atlantic sturgeon juveniles and adults in the Saint John River, NB					
Emily Van Diepen	BSc	100	0	1 May 2013	1 May 2014
Research Topic: Movement patterns of Atlantic sturgeon juveniles and adults in the Saint John River, NB					
Megan Cameron	BSc	10	0	1 May 2013	1 May 2014
Research Topic: Movement patterns and feeding ecology of Atlantic sturgeon juveniles in the Saint John River, NB					

b) Role, activities, and opportunities for training

Our HQP's are completely integrated into every facet of this research program. HQP prepare and deploy receivers, operate on and acoustically tag fish and attach archival pop-up 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 attached to free ranging sturgeon. This is currently being tested on an OTN white sturgeon in British Columbia**.** They assist in record keeping and data analysis, including submission of meta-data to the OTN data centre. 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 role that Minas Basin plays in the coastal migration of Atlantic sturgeon stocks on the east coast of North America.
4. Determine the importance of Minas Basin to the growth and health of Atlantic sturgeon (feeding, parasites).
5. Determine the movement of Atlantic sturgeon through Minas Passage and the potential impact of tidal power on east coast stocks.
6. Determine large and fine scale movement patterns, seasonal distribution and habitat use of Atlantic sturgeon from the Saint John River, NB, Canada.
7. Define critical river reaches of Atlantic sturgeon such as spawning sites and holding areas within the Saint John River. For example, the Mactaquac dam controls flow regimes and water levels which may have adverse effects on spawning, hatching and recruitment. Information on habitat utilization can be used to inform decision makers on management of water flow at the Mactaquac dam that will minimize impact on Atlantic sturgeon.
8. 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.
9. Describe habitat in the potential over-wintering area in the Bay of Fundy.
10. Continue to monitor movements, feeding ecology, and determine summer and winter aggregation areas of juvenile Atlantic sturgeon in the Saint John and Kennebecasis Rivers.
11. Collaborate with First Nations and local fishers to begin tagging Atlantic sturgeon in the Miramichi and Petitcodiac Rivers.
12. Improve scientific information on the existence and movements of Atlantic sturgeon stocks in eastern Canada
13. Improve communication and information transfer with researchers and managers in the United States concerning the migratory behavior and status of transboundary stocks of Atlantic sturgeon
14. Communicate our findings locally, nationally and internationally through meetings, presentations and publications.

b) Progress

1. Acoustic and Pop-up Archival Satelite Tags have provided new insight into the movement and migration of Atlantic sturgeon tagged in the Minas Basin, Saint John River and Gulf of Maine. Laura Logan-Chesney (MSc at Acadia) is now 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 then assessing population specific movement and migrational characteristice for acoustically-tagged sturgeon in Minas Basin and Minas Passage.

2. Laura Logan-Chesney is analysing 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 tgas), is providing new insights into distribution in Minas Passage in relation to proposed tidal power development.
3. Manuscripts detailing the feeding behaviour of Atlantic sturgeon in Minas Basin were published by McLean et al. in 2013 and 2014. These papers detailed the importance of Minas Basin as critical feeding habitat for Atlantic sturgeon.
4. 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 under revision in the *North American **Jo**urnal of Fisheries Management*.
5. A report has been 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. These fish will provide archival records of sturgeon movement through Minas Passage.
6. Beardsall, Stokesbury and Dadswell completed analysis of pop-up satellite archival tags deployed on sturgeon in Minas Basin which described passage through Minas Passage and lead to discovery of overwintering sites in the outer bay of Fundy.
7. The first, verified occurrence of shortnose sturgeon in Nova Scotia was found in an intertidal weir in Minas Basin during tagging work on Atlantic sturgeon.
8. 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).
9. Dadswell, Stokesbury and Litvak have been actively working with researchers in the USA (Balazik, Stokesbury [U. Mass]) to inform the conservation status of Atlantic sturgeon. See recent publications (Apostle et al. 2013, *Journal of International Wildlife Law and Policy* and Stokesbury et al. 2014, *Reviews in Fisheries Sceince and Aquaculture*) for transboundary issues and population status for Atlantic sturgeon from the USA and Canada.
10. McLean et al. presented results of our sturgeon program at the Fish Telemetrey Conference in South Africa in July 2013. Stokesbury presented results of tagged sturgeon moving through Minas Passage at the ICES AGM in Iceland, September, 2013.
11. 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 prepared a final manuscript that addressed this goal.

12. Bell deployed ultrasonic tags and conducted stable isotope analysis to begin to examine feeding and movement of Atlantic sturgeon juveniles in the Saint John River. Finished his Honours thesis.
13. 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 prepared a manuscript that addressed this goal.
14. Litvak and HQP monitored juvenile movements using stationary VR2W's and active tracking in the Saint John and Kennebecasis rivers. The extent of movements, 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.
15. Experimental gill net fishing was conducted in the Miramichi River in collaboration with the North Shore Micmac District Council's Aboriginal Aquatic Resources and Oceans Management group (NSMDC AAROM). Drift net fishing was also conducted with local fishers in the Petitcodiac River.

c) Significant deviations

There has been no significant deviation from the original objectives or plans. However, the project has become more complex and multifaceted. Aside from additions listed in the last annual report we are using double tagging to determine movement in Mans Passage. We arre also working with Dr. Wirgin (NYU Langone Medical School, NY, USA) to determine stock composition and population specific movements of Atlantic Sturgeon.

We have begun planning for acoustic tagging of Atlantic sturgeon in the Mira Estuary and Bras D'Or Lake regions of Cape Breton, a little studied region of the Atlantic coastal environment. No sturgeon were found in exploratory fishing in the Mira. However an unknown spawning aggregation of Striped Bass have been found. Striped Bass have been acoustically tagged (tags purchased by other funders, e.g. CWS). This project exploited the existence of the two OTN receiver lines off Halifax and northern Cape Breton, and is providing critical stock structure information for this COSEWIC designated threatened species.

Litvak has formed two new partnerships with First Nations groups: Fort Folly First Nation who work on the recovery of fish populations on the Petitcodiac River and the North Shore MicMac District Council Aboriginal Aquatic Resource and Oceans Management team (NSMDC-AAROM) who work on the Miramichi River. The inclusion of First Peoples environmental research groups in this program will not only increase our human resources allowing us to gain more and better information on Atlantic sturgeon, it will also increase the number of HQP's and provides direct interaction with the community that is closely linked to this important species in Atlantic Canada. Our objective this year was to deploy more tags in the Petitcodiac and Miramichi. We were not able to get the tags or VR2W's soon enough and thus were not deployed in these rivers. However, we were able to use this time to develop good connections with these two groups, scout the rivers, test new equipment for VR2W deployment in order to be ready to deploy the VR2Ws and tag fish this coming season.

These adjustments are normal expansions to a project of this nature and provide an economy of scales where we are more thoroughly able to meet our objective while also building research capacity and innovation at our (Acadia and Mount Allison) and other institutions.

d) Coordination and integration

Co-ordination of field work during the 2014 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 (Beardsall, Logan-Chesney, Buhariwalla and Stewart – Partly funded by OTN) to deploy receivers and tag fish in Minas Basin and in the Mira River. They also coordinated with and assisted Redden and Broome (ACER) in deployment of the additional receivers in Minas Passage. Litvak and his HQP personnel deployed receivers, tagged, sampled and tracked sturgeon in the Saint John River and estuary. They also spent time on the Miramichi and Petitcodiac Rivers to promote future collaboration with First Nations working on 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

Scientific:

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

- Passage into and out of Minas Basin occurs at mid-depths (20-60 m) in Minas Passage, but biases in the acoustic data set caused by decreased range for acoustic tags at high tidal flow rates (4-10m/s) may compromise the reliability of these findings. Work is ongoing coupling acoustic and archival technology to increase our knowledge of depth distributions at high flow
- The estimated size if the aggregation of Atlantic sturgeon in Minas Basin during the summer of 2014 was 25,000 adults and sub-adults. Both modified Petersen and modified Schnabel population estimates used were valid.
- Atlantic Sturgeon which aggregate in Minas Basin to feed during summer overwinter in the outer Bay of Fundy at depths of 60-110 meters and temperatures of 2-6C.
- During tagging work on Atlantic sturgeon in weirs of Minas Basin we verified the occurrence of shortnose sturgeon in Nova Scotia.
- An Atlantic sturgeon acoustially tagged in Minas Basin was detected by a grey seal bio-probe on the Scotian Shelf during Feburary, 2014. A second Atlantic sturgeon tagged in Minas Basin was acoustically detected of the mouth of the Peneobscot River, Maine during January, 2014.
- We have defined the Von Bertalanffy growth parameters for Atlantic Sturgeon from the Saint John River population.
- A total of 11 Atlantic sturgeon acoustically tagged in Minas Basin during 2010-2013 were acoustically recovered in the Saint John River spawning run during 2014.
- Spawning periodicity of 2-4+ years occurs in the Saint John River and males return after a shorter interval than females.
- Spawning is occuring in upstream areas of the Saint John River, but movements indicate that some fish are spawning in unsuitable downstream habitat or aborting spawning.
- A potential mixed-stock winter aggregation of adult Atlantic sturgeon occurs in the Bay of Fundy, offshore from the Saint John Harbour. Fish occupy depths of 40-110m and are found predominantly over sandy mud and moraine substrates.

- An adult Atlantic sturgeon tagged in the Saint John River was detected in the Riviere du Saint-Jean near the Saint Lawrence River approximately 1500km from the Bay of Fundy. The individual was later detected in the Minas Basin which required migration at a minimum of 44km/day.
- There is a potential for food competition between juvenile Atlantic sturgeon and shortnose sturgeon is occuring in the Saint John River.
- Juvenile Atlantic sturgeon primarily occupy the lower Saint John River and Kennebecasis River throughout the summer months. The majority of individuals were not detected in areas without saline influence. This is the first research on Atlantic sturgeon juveniles in the Saint John River.

Engineering:

- Litvak and HQP Taylor have developed a procedure that allows accurate (scale of meters) positioning of an acoustically tagged organism through triangulation using active tracking techniques. This is unique in the literature and when completed will be of importance to tag engineering companies. Paper to be submitted this month.
- Litvak and HQP Taylor collaborated with Sheng and HQP Ohashi to develop a backward particle drift model to determine the location of initial release of pop-up satellite archival tags. This method can provide significant advancements to understanding fine-scale marine habitat.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Stokesbury HQP Beardsall worked with OTN Pacific researcher McLean (co-supervisors Crossin [Dal] and Litvak [MAU]: OTN Pacific) to develop tag attachment technology. Litvak HQP Taylor also worked with McLean on this project to sample eggs and take blood from white sturgeon caught on rod and reel.

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

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

Litvak and Taylor collaborated with Jinyu Sheng and Kyoko Ohashi (Dal, OTN Atlantic) to develop a method of back predicting pop-up satellite archival tag release locations using oceanographic models for the Bay of Fundy. This provided a better estimate of actual release location from tagged Atlantic sturgeon allowing us to further explore potential over-winter areas in the Bay of Fundy.

Management articles have been completed with Apostle and VanderZwaag and collaborative science articles with Dodson, Castonguay, Cooke and other researchers in the OTN.

b) Interaction/Outreach to Broader Community

Our project provides proof of concept for the OTN Canada. 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.

Additonally the OTNC sturgeon project has had impacts at the regulatory level (i.e. Tidal Power impacts, stock structure and abundance for DFO stock status report, NOAA meetings). Also, knowledge and HQP transfer has occurred between the OTNC sturgeon project, between OTNC Atlantic sturgeon and oceanography projects (Litvak, Taylor, Taggart and Broell, Beardsall, Stokesbury, Logan-Chesney) and OTNG international partners (i.e., Heuple and Simpendorfer at James Cooke University, Matt Balazak, Virginia Commonwealth University, Kevin Stokesbury, U. Mass. and Ike Wirgin, NYU Langone Medical School, NY, USA).

The OTNC sturgeon project has deployed infrastructure in the Saint John River, the Minas Passage, Minas Basin and the Mira River. This has provided information for researchers to reach objectives of the sturgeon project; in the last year it has also positively impacted other 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).

Litvak's lab has furthered collaboration with NSMDC AAROM and began gill net fishing in the Miramichi River. Drift net fishing has also been conducted with local fishers in the Petitcodiac River. Connections with Fort Folly has been made and they have agreed to provide labour and help catch and tag Atlantic sturgeon on the Petiticodiac this coming year. The established collaborations are now in place and tagging and tracking of Atlantic sturgeon from these rivers 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.

Dadswell has continued to interact with the USA Atlantic Tracking Network, the Atlantic States Marine Fisheries Commission and fishers in the United States (Fox, Wirgin, Balazik and Platz) concerning the status of Atlantic coast populations of Atlantic sturgeon and their status.

9. Dissemination of information and results

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

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

Dadswell, M. J., Nau, G., and Stokesbury, M. J. W. (2014) First verified record of a shortnose sturgeon, *Acipenser brevirostrum*, LeSueur, 1818, in Minas Basin, Bay of Fundy, Nova Scotia, Canada. Proceedings of the Nova Scotia Institute of Science 47:239-255.

McLean, M., Dadswell, M. J., and Stokesbury, M. J. W. (2013) Feeding ecology of Atlantic sturgeon. *Acipenser oxyrinchus oxyrinchus* Mitcill, 1815, on the infauna of the intertidal mudflats of Minas Basin, Bay of Fundy. Journal of Applied Ichthyology 29:503-509.

McLean, M., Simpfendorfer, C. A., Heupel, M. R., Dadswell, M. J., and Stokesbury, M. J. W. (2014) Diversity of behaviour patterns displayed by a summer feeding aggregation of Atlantic sturgeon in the intertidal region of Minas Basin, Bay of Fundy, Canada. Marine Ecology Progress Series 496:59-69.

Spares, A. D., Dadswell, M. J., MacMillan, J., Madden, R., O'Dor, R. K., and Stokesbury, M. J. W. (2014) Too fast or 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.

Stokesbury, K. D. E., Stokesbury, M. J. W., Balazik, M. T., and Dadswell, M. J. (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.

b) Refereed journal articles (4 total) – submitted

Stewart, N. D., Dadswell, M. J., Leblanc, P., Bradford, R. G., Ceapa, C., and Stokesbury, M. J. W. Age and growth of Atlantic sturgeon from the Saint John River, New Brunswick, Canada. The North American Journal of Fisheries Management (March 2014).

Gibson, A. J., F., Halfyard, E. A., Bradford, R. G., Stokesbury, M. J. W., and Redden, A. R. Effects of predation on telemetry-based survival estimates: insights from a study on endangered Atlantic salmon smolts. Canadian Journal of Fisheries and Aquatic Sciences (21 May 2014).

Stokesbury, M. J. W., McLean, M. F., Redden, A. R., Beardsall, J. W., Broome, J., Bates, D., and Dadswell, M. J. Atlantic sturgeon spatial and depth distribution in Minas Passage, Nova Scotia: a region of future tidal power extraction. Transactions of the American Fisheries Society (March 2014).

Taylor, A.D. and Litvak, M. K. Quantifying a manual triangulation technique for aquatic ultrasonic telemetry. North American Journal of Fisheries Management (October 2014).

c) Conference presentations (1 total) – invited

Stokesbury, M.J.W., Beardsall, J., McLean, M., and Dadswell, M. J. (2014) Tagging and genetics reveal the origin of Atlantic sturgeon, *Acipenser oxyrinchus,* in Minas Basin, Nova Scotia: potential effects of local impacts on a mixed stock aggregation. Annual Meeting, American Fisheries Society, 17-21 August, Quebec City, Canada.

d) Conference presentations (12 total) – contributed

Stokesbury, M. J. W., Beardsall, J. W., Logan-Chesney, L., and McLean, M. F. (2014) Estimates of survival at varying temporal scales for fishes in the marine environment using electronic tagging technology. International Commission for the Exploration of the Sea, Annual Scientific Meeting, 15-19 September, La Caruna, Spain.

Beardsall, J. W., Stokesbury, M. J. W., and Dadswell, M. J. (2014) Atlantic Sturgeon behaviour in a marine macrotidal environment: archival and acoustic telemetry data from Minas Basin, Bay of Fundy. Annual Meeting, American Fisheries Society, 17-21 August, Quebec City, Canada.

Gibson, A. J. F., Halfyard, E., Bradford, R., Stokesbury, M. J. W., and Redden, A. M. (2014) Effects of predation on telemetry-based survival estimates: Insights from a study on endangered Atlantic Salmon smolts. Annual Meeting, American Fisheries Society, 17-21 August, Quebec City, Canada.

Buhariwalla, C., MacMilan, J., Wirgin, I., Stokesbury, M. J. W., and Dadswell, M. J. (2014) Residency and overwintering of Striped Bass, *Morone saxatilis*, in the Mira River Estuary, Cape Breton, Nova Scotia. Annual Meeting, American Fisheries Society, 17-21 August, Quebec City, Canada.

Redden, A. M., Broome, J., Keyser, F., Porskamp, P., Morrison, K., Baker, M., Stokesbury, M.J.W., and Wood, J. Challenges in monitoring fish and marine mammals in the megatidal waters of the upper Bay of Fundy. Annual Meeting, American Fisheries Society, 17-21 August, Quebec City, Canada.

Logan-Chesney, L. M., Stokesbury, M. J. W., McLean, M. F., Beardsall, J. W., and Dadswell, M. J. (2014) Atlantic sturgeon seasonality and spawning distribution in Minas Basin, inner Bay of Fundy, Canada. Poster Session. 4th annual Ocean Tracking Network Canada Symposium, June 2014, Ottawa, ON, Canada.

Stewart, N. D., Dadswell, M. J., Leblanc, P., Bradford, R. G., Ceapa, C., and Stokesbury, M. J. W. (2014) Age and growth of Atlantic sturgeon (*Acipenser oxyrinchus*) from the Saint John River, New Brunswick, Canada. Poster Session. 4th annual Ocean Tracking Network Canada Symposium, June 2014, Ottawa, ON, Canada.

Beardsall, J. W. and Stokesbury, M. J. W. (2014) Atlantic Sturgeon seasonal marine distribution in Bay of Fundy. 4th annual Ocean Tracking Network Canada Symposium, June 2014, Ottawa, ON, Canada.

Buhariwalla, C. F., Stokesbury, M. J. W., and Dadswell, M. J. (2014) Striped Bass overwintering in the Mira River estuary, Cape Breton, Nova Scotia. Poster Session: 4th annual Ocean Tracking Network Canada Symposium, June 2014, Ottawa, ON, Canada.

Spares, A. D., O'Dor, R. K., Dick, T., and Stokesbury, M. J. W. (2014) The Char Tracker. 4th Annual Ocean Tracking Network Canada Symposium. June 2014, Ottawa, ON, Canada.

Buhariwalla, C. F., Gregoire, M. J., Stokesbury, M. J. W., MacMillan, J. L., Wirgin, I. I., and Dadswell, M. J. (2014) Description and origin of Striped Bass, *Morone saxatilis* collected from a winter

fish kill in the southern Gulf of St. Lawrence. Oral Presentation: Science Atlantic Aquaculture & Fisheries and Biology Conference, March 2014, Halifax, Nova Scotia.

Stewart, N. D., Dadswell, M. J., Leblanc, P., Bradford, R. G., Ceapa, C., and Stokesbury, M. J. W. (2014) Age and growth of Atlantic Sturgeon (*Acipenser oxyrinchus*) from the Saint John River, New Brunswick. Science Atlantic Biology Conference, Halifax, N. S. April 2014.

10. Other contributions and deliverables

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

Dadswell, M. J. (2014) Tidal Power Impact on Fisheries in the Bay of Fundy. Interview and publication in Halifax Herald

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

Dadswell, M. J. (2014) Impact of tidal power development on the migratory organisms in the Bay of Fundy: the Scots Bay Project. Presentation at Acadia University.

Dadswell, M. J. (2014) Same talk as above presented to the Nova Scotia Striped Bass Society, Brooklyn, NS.

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

Dadswell, M.J. 2014. Impact of tidal power development on the migratory organisms in the Bay of Fundy: the Scots Bay Project. Presentation at Acadia University Biology Seminar series.

e) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, and/or Glider runs, as well as a contribution to a larger piece of work in any of the former

Redden, A. M., Broome, J., Keyser, F., Stokesbury, M., Bradford, R., Gibson, J. and E. Halfyard. 2014. Use of animal tracking technology to assess potential risks of tidal turbine interactions with fish. Proceedings of the 2nd international conference on environmental interactions of Marine renewable energy technologies (EIMR2014), 28 April – 02 May 2014, Stornoway, Isle of Lewis, Outer Hebrides, Scotland.

Redden, A. M, M. J. W. Stokesbury, J. Broome, F. Keyser, J. Gibson, E. Halfyard, M. McLean, R. Bradford, M. Dadswell, B. Sanderson and R. Karsten. 2014. Acoustic tracking of fish movements in the Minas Passage and FORCE Demonstration Area: Pre-turbine Baseline Studies (2011-2013). Final report to the Offshore Energy Research Association of Nova Scotia and Fundy Ocean Research Centre for Energy. Acadia Centre for Estuarine Research Technical Report No. 118, Acadia University, Wolfville, NS. 153p.

g) Data deposition to OTN Data Centre

Yes

k) Internet publishing, portal, blog, electronic publications

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

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

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

2014 – The Kentville Register - http://www.kingscountynews.ca/News/Local/2014-07-11/article-3793111/Sturgeon-beached-in-Scott%26rsquo%3Bs-Bay-remain-a-mystery/1

2014 – The Chronicle Herald - http://thechronicleherald.ca/novascotia/1219749-dead-scots-bay-sturgeon-spark-acadia-scientific-study

m) 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

o) 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

Litvak, Sheng, and HQP developed a method of back-predicting the location of pop-up satellite archival tags based on the location of the first satellite detection using oceanographic particle modeling.

r) Other

It is particularly important for the Network to document items that have been "delivered" to the following sectors, organizations and agencies:

The public (e.g., scientific outreach and education)

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 St. John River help in the St. 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 Strait, Strait of Belle Isle, Halifax Line).

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 of 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.

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 of Atlantic Sturgeon from the Saint John River population.

b) Contributions

Name of supporting organization: **CFI (OTNG)**	**Year 5** (2014)
Cash contributions to direct costs of research	59 k
In-kind contributions to direct costs of research	
13) Salaries for scientific and technical staff	
14) Donation of equipment, software	
15) Donation of material	
16) Field work logistics	
17) Provision of services	
18) Other (specify):	
In-kind contributions to indirect costs of research	
7) Use of organization's facilities	
8) Salaries of managerial and administrative staff	
9) Other (specify):	
Total of all in-kind contributions	59.0 k
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **CFI (LOF-Stokesbury)**	**Year 5** (2014)
Cash contributions to direct costs of research	3.5 k
In-kind contributions to direct costs of research	
7) Salaries for scientific and technical staff	
8) Donation of equipment, software	
9) Donation of material	
10) Field work logistics	
11) Provision of services	
12) Other (specify):	
In-kind contributions to indirect costs of research	
4) Use of organization's facilities	
5) Salaries of managerial and administrative staff	
6) Other (specify):	
Total of all in-kind contributions	3.5 k
Is this new funding (acquired during this reporting period)?	No

Name of supporting organization: **Acadia University**	**Year 5** (2014)
Cash contributions to direct costs of research	12.5 k
In-kind contributions to direct costs of research	
7) Salaries for scientific and technical staff	
8) Donation of equipment, software	
9) Donation of material	2.0 k
10) Field work logistics	4.0 k
11) Provision of services	1.0 k
12) Other (specify):	
In-kind contributions to indirect costs of research	
4) Use of organization's facilities	6.0k
5) Salaries of managerial and administrative staff	2.5 k
6) Other (specify):	
Total of all in-kind contributions	24.5 k
Is this new funding (acquired during this reporting period)?	Yes

Name of supporting organization: **NSERC (Engage-Stokesbury)**	**Year 5** (2014)
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	9.0 k
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	9.0 k
Is this new funding (acquired during this reporting period)?	Yes

Name of supporting organization: **Canadian Wildlife Federation**	**Year 5** (2014)
Cash contributions to direct costs of research	8.7K
In-kind contributions to direct costs of research	
1) Salaries for scientific and technical staff	4.0K
2) Donation of equipment, software	1.0K
3) Donation of material	
4) Field work logistics	3.0K
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	8.0K
Is this new funding (acquired during this reporting period)?	Yes

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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 2013 and January 2014 we recovered 12 of the 15 VMT and satellite transmitters deployed on grey seals on Sable Island in June 2013, and data from the eight Bluetooth units that were deployed in the southern Gulf of St. Lawrence in July 2013. Unlike grey seals deployed on Sable Island, those in the Gulf stayed very close to their deployment site suggesting a local abundance of prey. Data from the VMT units included 1,196 detections from seven OTN tagged marine species representing nine OTN projects. Due to their restrictive home range, only two seals deployed in the Gulf detected other marine species. Similar to the previous year, grey seal males from Sable Island interacted with bluefin tuna between late September and late October on the Eastern Scotian Shelf suggesting competition for the same resource and/or an area of high productivity. The detection of blue and porbeagle shark and snow crab were surprising given that only 20, 17 and 27, respectively, were tagged in 2013. A total of 1,668 seal-seal detections were also recorded involving 15 of the 23 seals that were tagged. Again, due to their limited movements, five of the eight Gulf grey seals accounted for 83% of all seal-seal detections. In June 2014, 16 grey seals from Sable Island were deployed with a VMT and satellite transmitter. Of these, one grey seal had a satellite transmitter with an integrated accelerometer to record head movements at sea, while another two seals had a Maritime Biologger accelerometer attached to the fur under the jaw to record jaw movements. We hope that data from these accerelometers will enable us to identify episodes of prey capture and confirm whether our conclusions derived from acoustic detection data alone are sufficient to indicate consumption vs non-consumption of tagged fish. With assistance from DFO and local fishermen, in July 2014 five grey seals were deployed with a Bluetooth VMT and satellite transmitter at the Magdalen Islands, 160 cod were tagged in November 2013 and May 2014 on the Eastern Scotian Shelf and 100 cod were tagged in May 2014 in the southern Gulf.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
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					

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Shelley Lang	RA	25	0	1 Jan 2010	31 Dec 2016
Research Topic: Combining dietary data and grey seal habitat use					
Laurie Baker*	MSc	100	100	1 Sept 2012	30 Oct 2014
Research Topic: Free ranging marine mammals: the next acoustic ships of opportunity					

**Note: Laurie Baker initially started her MSc with the Bioprobe Project during Phase I; in Phase II, her work continued as funded under Project 4.7, but was very intricately tied to activities in Project 4.8. Thus where her activities are most relevant to 4.8 outcomes, they are discussed there.*

b) Role, activities, and opportunities for training

Technical staff were responsible for analysis of grey seal and prey samples for diet analyses (fatty acid and stable isotope analysis), 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 VMT technology so that VMTs 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 2013 and January 2014 we recovered 12 of the 15 VMT and satellite transmitters that were deployed on grey seals on Sable Island in June 2013, and three of the eight Bluetooth units that were deployed in the Northumberland Strait, southern Gulf of St. Lawrence in July 2013. However, since the position and detection data from the units deployed in the Gulf are transmitted to satellite, we had access to data from all eight units. Unlike the grey seals on Sable Island, those that were deployed in the Gulf remained in a small home range close to their site of deployment, suggesting an abundance of prey close to their haul-out sites. Similar to previous years, the VMTs recorded a large number of seal-seal detections (n=1,668). Due to their restrictive home range, 83% of seal-seal detections were accounted for by five of the eight grey seals deployed in the Gulf. Transmitted data and those from the 15 recovered VMT units recorded 1,196 detections from seven OTN tagged marine species, namely Atlantic cod (21 individuals), Atlantic salmon (3), Atlantic bluefin tuna (17), porbeagle shark (3), blue shark (5), American eel (1) and snow crab (3). Due to their restrictive home range, only two seals deployed in the Gulf detected other tagged marine species (one snow crab and one bluefin tuna). Similar to the previous year, three grey seal males from Sable Island interacted with 12 individual bluefin tuna between late September and late October on the Eastern Scotian Shelf with patterns suggesting competition for the same resource and/or an area of high productivity. The detection

of blue and porbeagle shark and snow crab were surprising given that only 20, 17 and 27 individuals, respectively, were tagged in 2013. In June 2014, 16 grey seals from Sable Island were each deployed with a VMT and satellite transmitter. Of these, one grey seal had a satellite transmitter with an integrated accelerometer to record head movements at sea, while another two seals had a Maritime Biologger accelerometer (in collaboration with F. Broell, Project 4.3) attached to the fur under the jaw to record jaw movements. To date, we have assumed that consumption of a tagged fish by a seal would result in a specific, constant and very extended period of acoustic detections, however, to date this has not occurred with any encounters between grey seals and the tagged fish they have detected. Thus we have inferred non consumption. We hope that data from these accerelometers will enable us to clearly identify episodes of prey capture and confirm whether or not grey seals are foraging during specific patterns of acoustic encounters with tagged fish. These data will also contribute toward a better understanding of the behaviour of seals during travelling and when engaged in area restrictive search behaviour. With assistance from DFO Quebec Region and local fishermen, in July 2014 five grey seals at the Magdalen Islands were deployed with a Bluetooth VMT and satellite transmitter with the expectation that these units will continue to transmit through to spring 2015. In November 2013 Sean Smith (DFO Maritimes) tagged another 100 Atlantic cod with V13 tags on the Eastern Scotian Shelf, and another 60 were deployed in May 2014. Additionally, 100 cod were deployed in the southern Gulf of St. Lawrence through DFO Gulf Region. This brings the total number of cod tagged on the Eastern Scotian Shelf and in the Gulf to 1,092.

Through collaboration with Vemco and the Sea Mammal Research Unit, a research article describing the development and use of the Bluetooth linked VMT and satellite transmitter was published in Methods in Ecology and Evolution.

Laurie Baker completed her Masters thesis that evaluated the detection efficiency of the VMT acoustic transciever when deployed on grey seals, and which also quantified the spatiotemporal behaviour of seals in relation to prey detections to assess "sampling effort" in using seals as bioprobes. Distance between seals, wind stress, and depth were the important predictors of efficiency, with wind stress having the greatest effect on detection efficiency. Through access to raw acoustic transceiver data from Vemco, Baker was able to greatly improve our ability to identify legitimate periods of silence when the receiver recorded no part of an acoustic transmission, thus adding confidence to presence-absence data on fish abundance. This information will be important to interpreting data from VMTs that are being deployed on OTN gliders and on all gliders associated with the east coast "Gliderpalooza" deployments (most of which are carrying VMTs. Project 4.2), as well as to studies in the Arctic and Pacific that are using VMTs in place of normal Vemco VR2 and VR4 receivers. This work has been published in PLoS ONE. Additionally, a non-parametric Lagrangian method, T-LoCoH, was also applied to GPS location data to characterize patterns in individual and collective movement of instrumented grey seals. Consistent patterns in collective area-use emerged that may relate to seasonal energy requirements and prey distribution. This work highlighted the importance of access to the raw "ping" data collected by the tags, but not widely available to users. Access was made possible via close collaboration with VEMCO. The second paper on using bioprobes to sample the ocean, and whether such "sampling effort" is biased in time and space, has been submitted to Movement Ecology.

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

Objective c: Since 2009, we have been collecting detailed oceanographic data using the GPS satellite-linked transmitters deployed on each grey seal. Each transmitter records sea temperature, light, and depth every 10 seconds for the entire deployment period, thus we have detailed oceanographic data for

the entire deployment period (~6 months). A graduate student will be tasked with incorporating these data along with data on seal movements and habitat use into oceanographic models. Between March 2012 and Spring 2014, MSc candidate Karl Bryan Lagman, Richard Davis, Dr Katja Fennel and Dr John Cullen (Department of Oceanography, Dalhousie) deployed five GPS transmitters that are the same as those deployed on grey seals, in the Bedford Basin on day-long weekly deployments alongside a sampling device collecting a full suite of bio-optical measurements. These data will help calibrate the oceanographic sensors on the GPS tags and examine inter-tag variability in irradiance sensors embedded in the tags.

c) Significant deviations

No significant deivations occurred during this reporting period.

d) Coordination and integration

As in previous years, monthly meetings have continued with all co-investigators and HQP involved in the bioprobe project (4.7) and 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 November 2013 and May 2014, 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 May 2014, and L. Comeau and S. Leblanc conducted the surgery.

Collaboration between Vemco, the Sea Mammal Research Unit, Scotland and OTN has continued through the deployment of Bluetooth VMTs and satellite transmitters in the southern Gulf of St. Lawrence. Five Bluetooth VMTs and GPS units were deployed on grey seals at the Magdalen Islands in July 2014 with logistical support from Mike Hammill (DFO, Quebec) and local fishermen. These collaborations resulted in the above-mentioned publication in Methods in Ecology and Evolution.

Collaboration with B. Block and S. Wilson (Stanford University, CA) and M. Stockesbury (Acadia University, NS) led to the presentation of seal-bluefin tuna interactions on the Eastern Scotian Shelf at the 4th OTN Symposium, Ottawa, and at the 5th Biologging Symposium, Strasbourg. These presentations generated a lot of excitement about new uses of large predators as bioprobes in general. We are in the process of reaching agreement on a mutual publication.

In June 2014 we deployed two accelerometers on male grey seals on Sable Island, through collaboration with Maritime Biologgers, a newly established company headed by two OTN HQP (developed out of Project 4.3). Upon retrieval of the units in Dec 2014/Jan 2015, Maritime Biologgers will assist with the analysis of the data and help confirm whether grey seals were foraging during encounters with tagged fish and whether our conclusions derived from acoustic detection data alone are sufficient to indicate consumption vs non-consumption of tagged prey. Thus, these data will also contribute toward understanding the behaviour of seals during periods of travel and area-restrictive search.

e) Scientific and/or engineering significance

Through the use of the Bluetooth linked VMT and satellite transmitters, 13 grey seals have been deployed in the Gulf thus broadening our geographical sampling area and providing a more

representative sample of seal-seal, and seal-fish encounters. Interestingly, the behaviour of the eight grey seals deployed near PEI in 2013 and the five deployed at the Magdalen Islands in 2014 is similar, with individuals staying close to their site of deployment, exhibiting a restricted home range. This suggests an abundance of prey close to haul-out sites. The development of this novel bluetooth technology will permit the use of VMTs to be extended to other large marine species that can act as bioprobes of their ecosystems. As noted above, three grey seals on Sable Island were also deployed with head/jaw accelerometers in June 2013, two of which were designed and built by Maritime Biologgers, a new company formed by two OTN HQP. Assuming that these three seals will return to Sable Island in Dec-Jan, data from these deployments will allow us to test our assumptions about whether we can infer consumption of tagged prey from acoustic data alone and thus will help us better understand the foraging behaviour of grey seals and predation on prey during encounters with tagged fish.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

All members of the Bioprobe Team (Project 4.7) regularly meet and interact with Project 4.8 personnel and together work towards building new analysis and visualization tools. We have also collaborated with K. Fennel, T. Ross (Projects 4.1 and 4.2) to link oceangraphic features to predator foraging, to understand primary production, and to provide the oceanographic data our seals collect for their models. We worked extensively with HQP F. Broell (Project 4.3) to develop methonds for using their accelerometers to better understand inferred predation.

Bioprobe Co-PIs, HQP, and many collaborators, attended the 4th Annual OTN Canada-wide Symposium in Ottawa in June 2014. L. Baker and D. Lidgard (HQPs) gave presentations at the Symposium.

Bioprobe HQP and PIs helped plan and organize (and attended) the first international OTN data visualization workshop (Project 4.8).

Collaborations are underway on a paper examining the role of marine mammals in the marine ecosystem, a paper that will link the diets of grey seals, based on stable isotopes, with foraging style, and the use of the Template Model Builder to model the movement of grey seals at sea. L Baker and the Bioprobe Team collaborated extensively with Vemco to develop an agreement which would allow Vemco to share raw ping data (normally held only at Vemco) in order to considerably advance our analysis capabilities.

b) Interaction/Outreach to Broader Community

D Bowen had extensive discussions with colleagues from around the world on our bioprobe research and other OTN projects at the 20th Marine Mammal Confererence, Dunedin, New Zealand, Nov 2013.

D Lidgard gave a presentation on the research of grey seals on Sable Island including the work of OTN to Dept. Biology, St Mary's University, Halifax.

D Bowen, S Iverson and D Lidgard contributed technical details on the interactions of grey seals and Atlantic cod for the book 'Devil and the Deep Blue Sea' by Pannozzo that examined the ecological, social and political issues surrounding the Atlantic cod-grey seal debate.

S Iverson presented the Bioprobe work at the American Association for the Advancement of Science (AAAS) Meetings In Chicago in February 2014.

D Lidgard presented his work to the Dalhousie Marine Mammal class in February and August 2014, and presented work on grey seals and the use of telemetry to the Dalhousie SuperNova camp in August 2014.

S Iverson presented the Bioprobe work in a lecture to the new "Biologging and Biotelemetry" 3rd/4th-year course in the Department of Biology, Dalhousie in March 2014.

S Iverson presented the Bioprobe work in a series of seminars and lectures at five different institutions throughout Brazil in April and May 2014 and discussed with Brazilian collaborators possibilities for partner studies using the South American sealion.

S Iverson helped organize a special session ("From Science to Governance: Ocean Tracking Research for the Betterment of Canadian Marine Ecosystems and Resource Management") at the Coastal Zone Canada Conference in June 2014 and presented a lecture in the session based on the Bioprobe work.

D Lidgard was invited to present OTN work on predator-prey interactions at the Fifth Biologging Symposium, Strasbourg in September 2014.

S Iverson presented the Bioprobe work to the Universite de Bretagne Occidentale (UBO) and Institut Universitair European de la Mer (IUEM) in Brest, France, in September 2014.

In May 2014, along with other OTN HQP, D Lidgard presented results from the grey seal bioprobe project to the Nova Scotia Fisheries Minister, Keith Colwell.

9. Dissemination of information and results

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

Baker, L. L., Jonsen, I. D., Mills Flemming, J. E., Lidgard, D. C., Bowen, W. D., Iverson, S. J., and Webber, D. M. (2014) Probability of Detecting Marine Predator-Prey and Species Interactions Using Novel Hybrid Acoustic Transmitter-Receiver Tags. PLoS One 9: e98117.

Lidgard, D. C., Bowen, W. D., Jonsen, I. D., and Iverson, S. J. (2014) Predator-borne acoustic transceivers and GPS tracking reveal spatial and temporal patterns of encounters with acoustically-tagged fish in the open ocean. Marine Ecology Progress Series 501: 157-168.

Lidgard, D. C., Bowen, W. D., Jonsen, I. D., McConnell, B. J., Lovell, P., Webber, D. M., Stone, T., and Iverson, S. J. (2014) Transmitting species-interaction data from animal–borne transceivers through Service Argos using Bluetooth communication. Methods in Ecology and Evolution 5: 864-871.

b) Refereed journal articles (1 total) – submitted

Baker, L. L., Mills Flemming, J. E., Jonsen, I. D., Lidgard, D. C., Iverson, S. J., and Bowen, W. D. Quantifying the Spatiotemporal Behaviour of Grey Seals and their Detections of Acoustically Tagged Prey Species. Movement Ecology.

c) Conference presentations (2 total) – invited

Lidgard, D. C., Bowen, W. D., Jonsen, I. D., Block, B., Wilson, S., Stokesbury, M., and Iverson, S. J. (2014) Using acoustics to inform on the nature of species interactions with a roving marine predator in two large marine ecosystems. 5th Biologging Symposium, Strasbourg, France. 21-27th September 2014.

Iverson, S. J., and Gazit, T. (2014) From science to governance: grey seals and Atlantic cod. Coastal Zone Canada 2014 Conference, Halifax, NS. 16 June 2014.

d) Conference presentations (2 total) – contributed

Lidgard, D. C., Bowen, W. D., Jonsen, I. D., Block, B., Wilson, S., Stokesbury, M., and Iverson, S. J. (2014) Using the Vemco Mobile Transceiver to inform on the nature and spatiotemporal distribution of species interactions. 2014 OTN Symposium, Ottawa, ON. 3-5 June 2014.

Baker, L. L., Jonsen, I. D., Mills Flemming, J. E., and Iverson, S. J. (2014) Free-ranging Marine Mammals: The Next Ships of Opportunity?. 2014 OTN Symposium, Ottawa, ON. 3-5 June 2014.

10. Other contributions and deliverables

g) Data deposition to OTN Data Centre

All 2014 data arising from the grey seal bioprobe instrument deployments and the acoustic tagging of Atlantic cod were deposited in the OTN Data Center.

i) Books

D Bowen, S Iverson and D Lidgard contributed technical details on the interactions of grey seals and Atlantic cod for the book 'The Devil and the Deep Blue Sea: An Investigation into the Scapegoating of Canada's Grey Seal' by L. Pannozzo that examined the ecological, social and political issues surrounding the Atlantic cod-grey seal debate.

k) Internet publishing, portal, blog, electronic publications

D Lidgard published a blog (www.lidgardphotography.com/blog) on the June 2014 deployment trip to Sable Island.

o) 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

Three grey seals on Sable Island were deployed with accelerometers in June 2013, two of which were designed and built by Maritime Biologgers. Assuming successful recapture on Sable Island in Dec-Jan, these data will help us better understand the foraging behaviour of grey seals and inference of prey consumption from acoustic detection data.

L Baker's newest work demonstrated how a novel use of the statistical home-range method, T-LoCoH (Time integrated Lagrangian Convex Hull polygons), can provide an effective means to identify and quantify spatial and temporal trends in individual and collective area use and thereby account for biases in "sampling effort" by bioprobes as biological and oceanographic samplers.

11. Collaborations with industrial and government partners

a) Partners

The Department of Fisheries and Oceans Canada (DFO Maritimes, Quebec and Gulf) continue to be integral for the deployment of telemetry and data-logging instruments on grey seals and transmitter tags on Atlantic cod. DFO provides the 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 2014. They have also been 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 has 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 built two custom-made accelerometer tags for use on male grey seals. These tags were deployed in June 2014 and will be recovered in Dec-Jan. Maritime Biologgers will work with D Lidgard to analyse the data.

b) Contributions

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 5** (2014)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
19) Salaries for scientific and technical staff	6K
20) Donation of equipment, software	
21) Donation of material	
22) Field work logistics	45K
23) Provision of services	
24) Other (specify):	
In-kind contributions to indirect costs of research	
10) Use of organization's facilities	
11) Salaries of managerial and administrative staff	
12) Other (specify):	
Total of all in-kind contributions	51K
Is this new funding (acquired during this reporting period)?	yes

Name of supporting organization: **Canadian Foundation for Innovation (CFI)**	**Year 5** (2014)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
13) Salaries for scientific and technical staff	
14) Donation of equipment, software	182,171.45
15) Donation of material	
16) Field work logistics	
17) Provision of services	
18) Other (specify):	
In-kind contributions to indirect costs of research	
7) Use of organization's facilities	
8) Salaries of managerial and administrative staff	
9) 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 5 Review: 1 October 2013 – 30 September 2014

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, S. Vagle, G. Crossin, I. Fleming, J. Dodson, S. Cooke, A. Fisk

Collaborators: Keith Thompson (Dalhousie U), Steven Bograd (Southwest Fisheries Science Center, NOAA), Simon Bonner (U Kentucky), Mike Dowd (Dalhousie U), Chris Field (Dalhousie U), Jeremy Goldbogen (Cascadia Research Collective, Dalhousie U), Aaron McNeil (Australian Institute of Marine Science), Wayne Olford (U Waterloo), Martin Pedersen (Technical University of Denmark), Tim Stone (Vemco), Dale Webber (Vemco), Ian Jonsen (Macquarie University)

4. Public summary of report

This has been an exciting first year for our 'Visualization and modelling of complex marine observations' cross-cutting activity. We held our initial workshop ('Fitting state-space models with Template Model Builder) at Dalhousie University in July of 2014. It was very well attended and resulted in some major decisions being made with respect to the choice of software. It also helped to establish some new and already fruitful collaborations and was a great opportunity for participants to make some connections with the OTN Data Centre. Laurie Baker (4.7/4.8) sucessfully completed her MSc program in Fall 2014 while at the same time Kim Whoriskey commenced her MSc program. Our first postdoctoral fellow, Marie Auger-Méthé, joined us in August 2014 and has already begun a review paper in collaboration with fellow OTN members as well as created our first OTN GitLab account for the sharing of code, etc. PhD Stuart Carson's preliminary research was recently published in Ecological Modelling. Ian Jonsen has relocated to Australia but will remain a collaborator.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Stuart Carson	PhD	100	100	1 Jan 2012	31 Dec 2015
Research Topic: Statistical Methods for Marine Acoustic Telemetry Data					
Marie Auger-Méthé	PDF	100	100	1 Aug 2014	31 July 2016
Research Topic: Efficient and Robust State-Space Models for Animal Movement Data					
Kim Whoriskey	MSc	25	18	1 Sept 2014	31 Aug 2016
Research Topic: Robust State-Space Models for Animal Movement Data					
Laurie Baker *	MSc	100	0*	1 Sept 2012	31 Oct 2014
Research Topic: Free-Ranging Marine Mammals: The Next Acoustic Ships of Opportunity?					
Ian Jonsen	RA	100	100	1 Jan 2010	15 Mar 2014
Research Topic: Development and application of quantitative analyses and visualizations for tracking data					

**Note: Laurie Baker initially started her MSc with the Bioprobe Project during Phase I; in Phase II, her work continued as funded under Project 4.7, but was very intricately tied to activities in Project 4.8. Thus where her activities are most relevant to 4.7 vs. 4.8 outcomes, they are discussed in the appropriate places. However, since she was funded under 4.7, she is listed here as receiving $0 from this project's budget.*

b) *Role, activities, and opportunities for training*

Stuart Carson, who started his PhD in 2012, had a busy and productive year. In May, he successfully presented his Thesis Proposal to his Research Committee (similar to an Admission to Candidacy); this is a major hurdle for a PhD student and a significant milestone. Shortly after the Proposal's acceptance, he travelled to the Pan-American Institute for Advanced Studies in Spatial Statistics, where he attended a 2 week workshop. Among the attendees were some recognized experts in Spatial Statistics. The intensive workshop, in concert with a document summarizing the content, will be recognized as a directed study here at Dalhousie; fulfilling the last course work requirement for his degree. Shortly after returning from Brazil, he attended our initial workshop here at Dalhousie introducing TMB (template Model Builder), an important new R package for a large suite of models. Lastly, and perhaps most gratifying, his paper (co-authored with JMF), "Seal Encounters at Sea: A Contemporary Approach using R-INLA" was accepted and published in the November 2014 issue of Ecological Modelling, a successful result to much effort.

Kim Whoriskey officially started her MSc in Statistics at Dalhousie University September 1, 2014, and is being supervised by JMF. Currently her training includes classes required for her degree, but she has also participated in two workshops this year, including one hosted by the Canadian Statistical Sciences Institute entitled "Advancememnts to State-Space Models for Fisheries Science". She also attended the OTNC annual symposium of 2014, and presented a poster entitled "State-Space Modelling Frameworks: Behaviour, Capabilities, and Limitations when Applied to Animal Movement Data". Throughout her studies she will also be working as a tutor in the Learning Centre of the Department of Mathematics and Statistics.

Ian Jonsen provided quantitative modelling support to a number of OTNC and OTN-CFI related projects (Bioprobe, Sturgeon, Atlantic salmon). In conjunction with OTN-CFI and the Atlantic Salmon Federation, a state-space implementation of a Cormack-Jolly-Seber model was developed to estimate out-migration survival and re-observation rates of post-smolt Atlantic Salmon. Work was initiated on state-space models to analyse Atlantic Salmon and Atlantic Sturgeon movements from light-level geolocation tags. IDJ also co-supervised Laurie Baker's MSc research with JMF, leading to a publication in PLoS One and a successfully defended thesis in September 2014. A second manuscript will be submitted to Movement Ecology in the coming weeks. IDJ left OTNC at end March 2014 for a senior research fellowship at Macquarie University, Sydney Australia.

Laurie Baker (shared between projects 4.7 and 4.8) completed her MSc program requirements in fall 2014. Before doing so she attended the 2014 International Statistical Ecology Conference. This conference was an incredible learning opportunity and greatly expanded her knowledge of the statistical approaches used to answer a variety of ecological questions. She received great feedback on her work, and gained additional insights on what current techniques may be applied to the analysis of mark-resight data from a number of distinct fields including genetic sequencing. The conference was a great opportunity to promote OTN and the knowledge and data sharing capabilities offered by the network.

This conference brought together world-renowned statistical ecology experts working on topics from movement behaviour to survey design. The timing of the statistical ecology conference, less than a month after the OTN annual symposium, also meant that Laurie was abreast of much of the exciting and new research being carried out by other OTN researchers. As a result, she was able to discuss areas of the OTN other than her own research. These include: fish migrations, fish survival, animal movement, and the pairing of these data to ocean models.

Marie Auger-Méthé started her post-doc with OTN on August 1st 2014. Just prior to her start date she participated in our first workshop. Marie's main role is to develop improved methods for fitting animal movement models to OTN 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 members of OTN (e.g. Dr. Ian Fleming, Dr. Glenn Crossin) to develop models to address questions specific to their study species. She is also writing a manuscript describing new approaches for fitting state-space models to marine data. To help dessiminate the use of the tools she is developing, she has been posting the tools online via the OTN GitLab account (https://utility.oceantrack.org/gitlab/maugerme).

6. Progress towards objectives/milestones

a) Overall objectives

This cross-cutting activity 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

Our first objective was to organize an annual workshop to bring together OTN HQP and experts in data visualization and statistical modelling. Our inaugural workshop took place Jul 28 - 30 2014 at Dalhousie University in the Steele Ocean Sciences Building. It was at capacity with 20 participants, including 10 HQP and 4 experts in statistical modelling.

Our second objective was to create a repository of documented shared code and freely available software. Jonathan Pye has posted the code used in the inuagural workshop on the OTN GitLab website (https://utility.oceantrack.org/gitlab/otn-hqp/otn_tmb_workshop_2014) and is freely available online. To help ecologists use the techniques explained in the workshop on their own data, MAM has inserted inside the posted code extended explanations of the analysis used. In addition, MAM is maintaining an open and public project on the OTN GitLab website (https://utility.oceantrack.org/gitlab/maugerme/tmb-tools) that serves as repository of tools to use TMB, a new and highly efficient software used to fit state-space models. Finally, MAM has 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 will be open to the public and a link will be added in the published article, thus allowing all readers access to the code. Additionally, MAM is leading a small class in Feb 2015 on how to visulalize and handle spatial data in R, a powerful and freely available software. All the material from the class, including a set of tutorials, will be posted online and available to the public.

c) Significant deviations

Our first workshop was held in July rather than in November or February as originally proposed.

We decided to focus first on the development of a statistical modeling framework before delving into scientific and data visualization. We anticipate that our platform of choice (R/TMB) will have sufficient power to produce any visualizations that will be required.

Initial Collaborators Steven Bograd, Simon Bonner, Jeremy Goldbogen and Wayne Oldford have been replaced by Anders Neilsen and Christoffer Moesgaard Albertsen, both from the Technical University of Denmark and IDJ from Macquarie University.

d) Coordination and integration

OTN Canada partcipants D. Bowen, G. Crosssin and I, Fleming, S. Cooke and A. Fisk (the latter two represented by HQP) attended the inaugural workshop along with collaborators Chris Field and Tim Stone.

e) Scientific and/or engineering significance

In order to answer scientific questions of relevance to the OTN, we must have both accurate models and effective visualization tools. Understanding the spatial ecology of marine animals and predicting how their distribution will be affected by anthropogenic factors (e.g., climate change, fishing) is complicated by the dynamic and 3D nature of the ocean and the challenges associated with marine data. Thus models for marine animals are incredibly complex and difficult to fit to data and visualising their results is challenging. JMF's research group is using new techniques that can accurately and robustly fit complex models to data in the fraction of the time required before. These new techniques will allow one to fit intricate movement models to the very large data sets of OTN, with an unforseen speed and accuracy and thus allow members to answer ecological questions that were out-of-reach before.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

a) Intra-network collaboration and partner meetings

Full attendance at our inaugural workshop speaks to the integration and international collaboration occurring as a direct result of this CCA.

The focus of our initial year was on the development of a statistical modeling framework suitable for OTN initiatives across the network. As such, our inaugural workshop brought together OTN Collaborators and HQP with relevant experts. This workshop took place Jul 28 - 30 2014 at Dalhousie University in the Steele Ocean Sciences Building. It was at capacity with 9 OTN HQP (David Yurkowski, Laurie Baker, Melanie Beguer, Kristin Boe, Nathan Furey, Eddie Halfyard, Marie Auger Methe, Stuart Carson, Kim Whoriskey), one additional HQP (Easton White – PhD student at UC Davis), 4 OTN collaborators (Don Bowen, Ian Jonsen, Ian Fleming, Joanna Mills Flemming), 2 statistical

modeling experts (Christoffer Albertsen and Chris Field) and finally 2 OTN Data Managers (Lenore Bajona and Jon Pye). Fred Whoriskey formally opened the workshop.

Following this workshop we are fully confident that our platform of choice (R/TMB) will have sufficient power to perform any statistical modeling required as well as produce any desired data visualizations. Jon Pye, via the OTN sandbox, has since installed R Studio and TMB so that collaborators can access the packages. To help disseminate the tools that Marie Auger Methe has since been developing in TMB, she has posted then online via the OTN GitLab account (https://utility.oceantrack.org/gitlab/maugerme).

JMF serves on both the International Scientific Advisory Committee for the OTN as well as the Data Management Committee.

b) Interaction/Outreach to Broader Community

KW and MAM have been invited to speak at a session (proposed by JMF) titled " Using TMB to quickly and robustly solve problems in marine ecology" at the Statistical Society of Canada Annual General Meetings.

In addition, MAM has been invited to speak at a session entitled "Dynamics of biological systems" at the Canadian Mathematical Society Winter Meeting. Her talk entitled "Tackling the challenges of fitting movement models to marine data" will showcase the work of OTN.

9. Dissemination of information and results

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

Carson, S. and Mills Flemming, J. E. (2014) Seal encounters at sea: A contemporary spatial approach using R-INLA. Ecological Modelling, 291:175-181.

Cosandey-Godin, A., Krainski, E. T., Worm, B., and Mills Flemming, J. E. (2014). Applying Bayesian spatiotemporal models to fisheries bycatch in the Canadian Arctic. Canadian Journal of Fisheries and Aquatic Sciences (Published on the web 29 September 2014, 10.1139/cjfas-2014-0159).

Martins, E. G., Gutowsky, L. F. G., Harrison, P. M., Mills Flemming, J. E., Jonsen, I. D., Zhu, D. Z., Leake, A., Patterson, D. A., Power, M., and Cooke, S. J. (2014) Behavioral attributes of turbine entrainment risk for adult resident fish revealed by acoustic telemetry and state-space modeling. Animal Biotelemetry, 2:13.

Pollet, I., Ronconi, R., Jonsen, I. D., Leonard, M., Taylor, P. D., and Shutler, D. (2014) Foraging movements of Leach's storm-petrels, Oceanodroma leucorhoa, during incubation. Journal of Avian Biology 45:305-314.

b) Refereed journal articles (1 total) – submitted

Hussey, N. E., Kessel, S. T., Aarestrup, K., Cooke, S. J., Cowley, P. D., Fisk, A., Harcourt, R. G., Holland, K. N., Iverson, S. J., Kocik, J. F., Mills Flemming, J. E., and Whoriskey, F. G. (2014) Aquatic animal telemetry across diverse scales: discovery, applications and relevance, submitted to Science.

c) Conference presentations (0 total) – invited

d) Conference presentations (3 total) – contributed

Baker, L. L. (2013) International Council for Exploration of the Seas (Reykjavic, Iceland): Detection Efficiency of Vemco Mobile Transceivers Deployed on Grey Seals (Halichoerus grypus) on the Scotian Shelf.

Baker, L. L. (2014) International Statistical Ecology Conference (Montpellier, France): Free-ranging marine mammals: the next ships of opportunity?

Whoriskey, K. (2014) OTN Annual Symposium (Ottawa, Canada): State-Space Modelling Frameworks: Behaviour, Capabilities, and Limitations when Applied to Animal Movement Data.

10. Other contributions and deliverables

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

JMF was awarded a Collaborative Research Team projects by the Canadian Statistical Sciences Institute. OTNC is a partner organization.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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 initiated a project that aims to quantify marine behaviour and potential responses of salmonid fishes to climate change, both in (1) areas of species transition and (2) in areas that are among most northern salmonid habitats. Two PhD students and a postdoctoral fellow were recruited. Our work in species transition areas involved three study sites in 2014, stretching from the Campbellton River (49.2 N) to Parkers Brook (Pistolet Bay, 51.5 N) to Gilbert Bay (52.4 N). At Campbellton River, both smolt and kelt Atlantic salmon were tagged and early results indicate distinct migratory differences, with kelt leaving the inner bays sooner than smolt. 27% of the kelt returned the same year to ascend the river and breed again. Carryover research (molecular analyses) from Phase I at Campbellton indicates that at outmigration kelts that survived to return to breed again (i.e. repeat breeders) do not differ in regards to infection levels (examining for 46 salmon pathogens) than those that do not. There are, however, weak indications of muscle, and particularly gill transcriptome differences between the two groups at outmigration, suggesting a possible link to survival. Research at Parkers Brook was severely inhibited by anomalous ice conditions that last late into the spring. Despite this, we obtained value information on overwintering behaviour of Arctic char, and to a lesser extent Atlantic salmon, indicating extensive use freshwater ponds (lakes). In Gilbert Bay, both species were tagged in early summer and hydrophones retrieved in October, but data analyses are yet to be undertaken.

This was the second year of successful fieldwork with Arctic charr in areas that are among most northern salmonid habitats, the Cambridge Bay region. An acoustic array of 42 receivers had been deployed in 2013 and all were successfully retrieved and redeployed in 2014. Sixty individual charr were tagged in 2014, bringing the total number of tracked individuals to 120. The data downloaded this year is currently being analyzed by PDF Moore. CTD casts were conducted along systematic transects in the area in both 2013 and 2014 to link charr migrations with physical variables.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Ingeborg Mulder	PhD	100	100	1-Sept-14	31-Aug-18
Research Topic: Nearshore marine habitat use by Arctic charr: competetive interactions with other salmonids					
Kristin Bøe	PhD	100	60	1-May-14	30-Apr-18
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-Jul-2013	Dec-2015
Research Topic: Analysis of data collected from an array of 42 acoustic receivers					

b) Role, activities, and opportunities for training

Project Component 1 - Salmonids in the species transition zone

Component 1 provides opportunities for two PhD students, Ingeborg Mulder and Kristin Bøe. 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 and Atlantic salmon data, respectively. They will be trained in telemetry data 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. 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 their northern distribution

Jean-Sébastien Moore (PDF) planned and participated in the 2014 field season and spent over 2 months in the Arctic. He collected the data from an array of 42 acoustic receivers and performed maintenance on all units. He is currently working on analyzing the data.

6. Progress towards objectives/milestones

a) Overall objectives

Project Component 1 - Salmonids in the species transition zone

The aim of the first project component is 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 two regions of species transition (Newfoundland/Labrador and Ungava Bay). 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 their northern distribution

To study the movement and feeding ecology of Arctic charr, the northern most salmonid and important subsistence and commercial fish species.

b) Progress

Project Component 1 - Salmonids in the species transition zone

PhD students were selected after completion of a recruitment process in early 2014. Kristin Bøe began in May 2014 after being granted admission to the PhD program at Memorial University of Newfoundland and obtaining the necessary student visas for entry to Canada. She immediately began research at Campbellton River and assisting with that at Pistolet Bay (Parkers Brook) and this continued throughout the summer. Ingeborg Mulder began in September 2014 after being granted admission to the PhD program at the University of Waterloo and obtaining the necessary student visas for entry to Canada. As of September 2014, both students have emphasized the completion of associated course work and the PhD proposal defense process.

Research was undertaken at three locations along the Atlantic salmon - Arctic char transition zone of the coasts of Newfoundland and Labrador (Campbellton River, Parkers Brook and Gilbert Bay). Our study has progressed successfully to date.

Campbellton River (north shore Newfoundland)

During a five day period in May, 54 kelts (mean length 59.03 cm ± 5.39 SD) and 24 smolts (mean length 23.00 cm ± 3.74 SD) where captured and tagged at the DFO counting facility at Campbellton River (SFA4), Notre Dame Bay NL. Campbellton River holds the southernmost population of salmon to be tagged in this project and has an average annual run of approximately 3500 adults. The relative high return rate of kelts combined with the yearly deployment of counting facilities during the smolt and adult runs provides a unique opportunity to use data storage tags in this system. All kelts were fitted with PIT tags and Lotek LAT 4300 tags (Beta versions supplied independently by Lotek) with temperature, pressure and light sensors. Of the 54 kelts, 48 were also tagged with Vemco acoustic transmitters with a battery life from 61 to 676 days (Table 1). Some of the smolts fitted with acoustic transmitters were large enough to potentially return as precocial post smolts the same summer. An additional 100 smolts were externally tagged with Lotek dummy tag (separate project) to assess a new method of smolt tag attachment.

Caudal and adipose fin tissue were collected from all adults which will be used for later genetic work and possibly isotope analysis. Unusually low temperatures (even snow at one point) led to a quick recovery of most fish, and no mortalities were recorded during the tagging period.

Table 1. Salmon acoustic tag deployments, Campbellton River May 2014

Acoustic tag model	Life stage	Expected battery life (days)	*N*
V8-4x	Smolt	61	26
V9-1x	Smolt	102	2
V8-4x	Kelt	61	4
V9-1x	Kelt	102	33
V13-1x	Kelt	676	11

With the help from DFO, 31 VR2W hydrophones were deployed in the Bay of Exploits within Notre Dame Bay, NL, during 21-22 May. The straits leading out from the bay were all covered by 1 to 3 hydrophones to detect fish leaving the array so that survival in the early near-shore migration phase can be estimated. Receivers were positioned in the bay of Exploits to detect potential straying individuals, and in Campbellton River ca. 1 km upstream of the counting fence to detect fish passing the fence without being captured. To this date, only four of the 31 receivers has been collected and downloaded, these were located on the outer boundary of Bay of Exploits, Notre Dame Bay. The plan is that a crew from DFO together with an HQP will collect the remaining hydrophones by the end of November.

From the end of May through June, 32 kelts and 17 smolts were detected at least once by one of the four hydrophones recovered thus far (31 deployed). In July, this declined to 15 kelts and 5 smolts detected and dropped further in August to 5 kelts and no smolt detected. As evident from Figure 1, the kelts passed the hydrophones distinctly earlier than the smolts, despite having been tagged and released at similar times. Furthermore, kelts that appeared to pass the hydrophones later in the season than others, tended to be those that appeared to linger in the area. Twenty-two of the kelts were also detected by DFO hydrophone arrays (Dr. John Brattey) stationed oustside the Bay of Exploits. Three of these kelts were not detected by the four hydrophones within the Bay of Exploits we have downloaded thus far. To date, detections have been recovered for a total of 36 of the 48 kelts tagged and there remain 27 hydrophones to recover and download.

An unusually warm summer and low precipitation levels led to a slow start to the upstream migration of the salmon in 2014. For prolonged periods the salmon run came close to a halt and did not pick up again until temperatures dropped in mid-August. Eight of the 54 kelts were recaptured at the DFO counting facility as consecutive spawners during a three day period following this temperature drop. The Lotek tags were retrieved and successfully downloaded giving complete temperature and depth time-series for 7 out of the 8 tags. These data currently await further analysis of irradiance measurements to estimate geolocations. Positions as detected by the acoustic array will serve as a means to confirm or reject geolocations and potentially improve the accuracy of the movement trajectories inferred from the geolocation data. Tissue from the recaptured fish is currently being stored for subsequent isotope analysis with the aim of investigating marine feeding ecologies of repeat breeding and grilse salmon. An additional eight returning kelt were detected by the hydrophones placed upstream of the counting fence during the same time period as the 8 recaptures were made, giving a total return rate of 27 % this year. These fish probably escaped due to the high numbers of fish being processed during this period (up to

500 fish daily). Some of these are likely to be recaptured at the smolt counting fence during the downstream migration in spring 2015 and the data storage tags can be retrieved at that point.

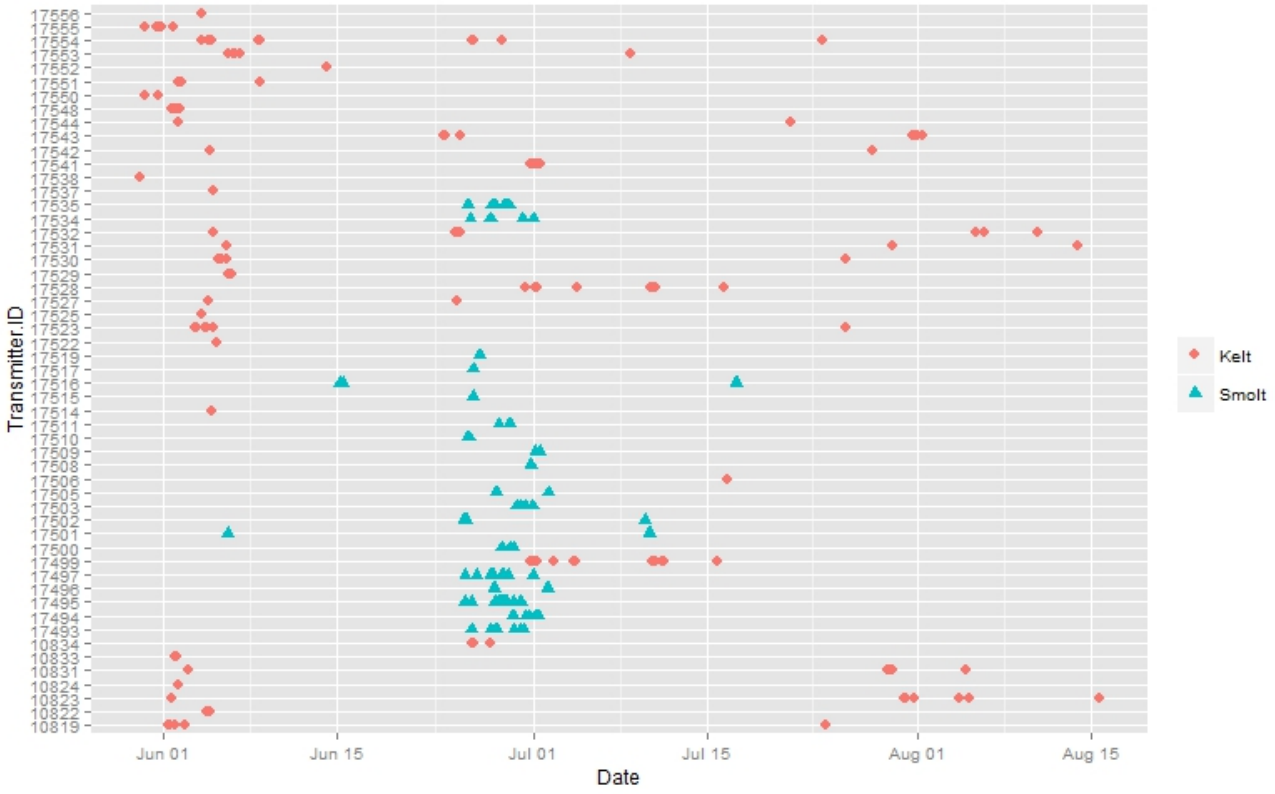

Figure 1. Detections of acoustically tagged Atlantic salmon kelt and smolts at 4 of 31 hydrophones recovered from the Bay of Exploits, Notre Dame Bay, NL, thus far.

Campbell River (molecular analysis of single & repeat breeders - carryover from Phase1)

In collaboration with Dr. Kristi Miller and Karia Kaukinen of DFO's Pacific Biological Station, we assessed the physiological variance between single and repeat spawners by comparing infection status in gill tissue and conducting a functional genomic study in gill and muscle tissue. A microfluidics quantitative PCR platform that can simultaneously assess 96 assays against 96 samples to determine the presence and load of 46 salmon pathogens in 51 non-destructively sampled gill tissue samples we used to compare infection rates. Analysis provided information on the presence and load of a broad range of pathogens, but was not conducted in such a way to establish whether the fish were showing signs of disease, which would have required histology samples, something that is just not possible for non-destructively sampled fish. Of the 51 samples, nine were from repeat spawners and 42 single spawners. All fish carried at least one pathogen, with a range of 1-5 and mean of 2.3. Five pathogens were commonly observed in both single and repeat spawners, but none were differentially observed between single and repeat spawners, either based on prevalence or load. Interestingly, one of the repeat spawners had detections for four pathogens at moderate load.

In the gneomic study examining the transcriptome of gill and muscle tissue, we expected that there would be more than one cause of mortality (in single spawners), hence we knew that it may be difficult to resolve signatures explaining only a portion of variation associated with survival in limited sample of fish. However, we took on this analysis as a preliminary assessment to see if there was anything glaring. Eight samples of repeat spawners and fourteen of single spawners were run on gill microarrays. A t-test between single and repeat spawners did not yield a strong signature (only a few genes significant), hence we conducted conducted principal components analysis (PCA) as a form of data reduction to identify the main sources of transcriptional variation in the data, and then analysed the differentiation between repeat and single spawners along each of the top three axes. PC1 was associated with technical variance, hence was not considered further. PC3, however, was significantly associated with repeat spawning (t-test of rotational values yielded a $P<0.001$), with seven of the eight returning fish having negative rotational values and only two single spawning fish, and twelve of the fourteen single spawners with positive rotational values (Figure 2). PC3 accounted for less than 5% of the variation, so the signature was still rather weak. Protein turnover (both biosynthesis and catabolism) was down-regulated in single spawners, while oxidative phosphorylation and lipid degradation were up-regulated in single spawning fish. There were no signals associated with differential regulation of the immune response as we have observed previously in Pacific salmon. Protein biosynthesis is often turned down in stress responses to conserve energy. For muscle, we ran samples of 8 repeat spawners and 17 single spawners. With PCA analysis, none of the top 3 PC's were correlated with repeat spawning and there were no strong clusters differentiating spawning groups resolved along the PC1-3 axes of the muscle transcriptome. A t-test weakly resolved 157 genes ($P<0.005$), but only one unknown gene that was significant at $FDR<0.05$. Repeat spawners did cluster separately from single spawners using this genelist, although there was a high degree of variation of genes within and between groups.

Parkers Brook (also known as Western Brook; Pistolet Bay, northern peninsula of insular Newfoundland)

In July 2013, we caught, tagged and released 9 Atlantic salmon (mean length 58 cm ± 3.3 SD) and 25 Arctic charr (mean length 46.5 cm ± 5.7 SD) during their upstream migration at the entrance of Parkers Brook. At that time, two hydrophones were deployed at the river mouth tagging site and another in Western brook Pond, ca. 5 km upstream. Several fish were detected at the upstream hydrophone by late October, when the receiver was downloaded, and we suspect fish overwintered in this pond. During the July-October period, > 140,000 detections were recorded, suggesting that the site is favorable for collecting data. We successfully detected 21 fish to have entered the pond, however, most of these fish were charr (17) and only 4 salmon were determined to have migrated upstream. One tagged salmon was caught during the angling season and the tag returned to DFO officers at St. Anthony. It is possible that other salmon were also angled in the river; however, it is more unlikely that charr would have been angled as few anglers report catching charr in the river, as compared to salmon.

We successfully retrieved and downloaded data from the receiver in Western Brook Pond during Spring 2014. There were 1.2 million detections from > 20 fish throughout the winter months, particularly near the time of outmigration (these data are just beginning to be analyzed). The receiver at the mouth of Parkers Brook detected fewer fish leaving the pond, and we suspect that detection ability was low in high flow conditions (increased noise, bubbles, sediment) at the time of outmigration. It did detect some fish outmigrating in early May, which is somewhat earlier than expected. This is informative, as future efforts to tag fish prior to outmigration will need to target an earlier time period, probably late April. Unfortunately, extremely late and unusually heavy sea ice conditions in Spring 2014 prevented us from deploying hydrophones and tagging fish in the marine environment. Without fish to tag, there was little

value in deploying receivers, particularly when the sea ice conditions delayed our deployment schedule by > than a full month.

Given the wealth of data collected in the fresh water (western Brook pond) and the difficulties caused by sea ice in the marine environment in 2014, we decided to deploy additional hydrophones in fresh water to increase winter habitat coverage during 2014/2015. Four hydrophones were deployed in two ponds to detect the extent of winter movement and possibility of fish moving between different ponds. We also tagged an additional 15 Arctic charr at Parkers Brook during 14-18 July 2014.

We are quite pleased with the level of local support and community interest at the Parkers Brook study site, which has produced great opportunities to utilize local media (newspaper) to increase awareness of our study. Despite the delays as a result of unusual sea ice conditions in 2014, we remain postive about the opportunities for studying salmonid (salmon-charr) interactions near the southern extreme for anadromous Arctic charr.

Gilbert Bay (southern Labrador)

We initiated our OTN study in Gilbert Bay in 2014 by tagging 20 Arctic charr and 20 Atlantic salmon. These fish were successfully caught, tagged, and released in the marine environment, and the study builds on earlier work on Arctic Charr in Gilbert Bay. There was an abundance of both species available in the marine environment. The existing receiver network in Gilbert Bay has been maintained (DFO network of receivers) and data were downloaded in early October, but are not yet analyzed. Based on satellite phone conversations with DFO technical staff at the site, no Atlantic salmon tagged in Alexis Bay during June 2014 had returned to the Alexis River as of October, though many of charr had returned to the Shinneys River and entered Shinneys Pond. These latter fish will provide valuable data on overwintering behaviour. We are building on earlier research successes with Arctic charr in the area and are strengthening collaborations with local the angling community and with the NunatuKavut.

In summary, our first field season for phase II of OTN represents significant progress towards our objectives. Graduate students were recruited (though some delays were encurred), appropriate field sites chosen, and research initiated. Comparable data in terms of migration timing, marine behaviour and freshwater habitat use were collected. Ice conditions did, however, limit our work at Parkers brook, Pistolet Bay, which we plan to address during 2015.

Project Component 2 - Arctic char in their northern distribution

This year was the second year of successful Arctic charr fieldwork in the Cambridge Bay region, where an acoustic array of 42 receivers had been deployed in 2013. All 42 units were succesfully retrieved and redeployed in 2014, and the data was downloaded and maintenance was performed on the units. An addditional 60 individual charr were tagged in 2014, bringing the total number of tracked individuals to 120. The data downloaded this year is currently being analyzed by PDF Moore. Preliminary results of the 2013 field season were presented at the ArcticNet meeting in Halifax in December 2013. The 2014 data re-inforced the conclusions of last year's preliminary work, and two publications are currently being prepared. In addition, CTD casts were conducted along systematic transects in the area in both 2013 and 2014 to link charr migrations with physical variables.

c) Significant deviations

Project Component 1 - Salmonids in the species transition zone

There were no significant deviations from the proposed research plan for 2014. Ice conditions in Pistolet Bay, however, did limit our abilities to undertake research there. As a result, we will need to return to Pistolet Bay in 2015. We also anticipate not being able to effectively undertake studies at Ungava Bay [Michael - need a brief explanation why], thus will refocus and expand our efforts on the Labrador coast.In anticipation of commencing studies in Ungava in 2015, some preliminary work was completed in Dry Bay where anadromous Arctic charr are known to exist. Placement of temperature monitors encountered several problems associated with the exceptionally high tides throughout Ungava Bay (Equivalent or exceeeding those of the Bay of Fundy), with monitors being left exposed for long periods, covered in silt or removed by tidal action. Thus placement of accoustic recievers would require constant site monitoring beyond the capability of the project budget. It is possible that DSTs may be deployed as there is a counting fence run annually on the Nephigee River, although discussions with the local Inuit would need to be completed and permission sought owing to the fact that the river is on Category 1 listed for the exclusive use of the Inuit.

Project Component 2 - Arctic char in their northern distribution

No significant deveiations for our project.

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 will work closely together, one focusing on Atlantic salmon (K. Bøe) and the other on Arctic charr (I. Mulder), and as such supporting each other logistically as well as through the cross-fostering of ideas, knowledge and expertise. 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. Moreover, Corey Morris and Martha Robertson are playing instrumental roles in the field research and working closely with the PhD students on this. We have also had formal grouping meetings (co-PIs and collaborators; in person and/or by phone) to discuss project design and progress (26 June 2013, 9 April, 17 June and 28 October 2014). With regards to the development of data storage tags (DSTs) and attachment methodology, there has also been regular communication and meetings with Lotek Wireless in St. John's.

Project Component 2 - Arctic char in their northern distribution

There were regular phone calls between PDFs Moore, Hussey, Kessel and PIs Fisk and Tallman regarding the field work in Cambridge Bay.

e) Scientific and/or engineering significance

Project Component 1 - Salmonids in the species transition zone

This study is designed to address a significant knowledge gap in our understanding of the comparative temporal and spatial (location, depth, temperature) marine habitat use of these salmonid species, particularly in sympatry, and the implications for prey resource use, growth and reproductive development. Moreover, dispersal is likely to be a crucial part of how these species respond to climate

change and understanding the marine migrations will thus help predict the species' response to changing environmental conditions. For instance, dispersal, or straying, has the potential to move genes around the landscape and can be an important parameter to consider when predicting the evolutionary response to a changing climate. From a practical standpoint, Arctic charr and Atlantic salmon are central to important subsistence (food) and recreational fisheries, and in some cases commercial fisheries, as well as in social and ceremonial fisheries for aboriginal peoples (e.g. along the Labrador coast, the Metis, Innu and Inuit).

With regards to the engineering significance of our research, we continue to work with Lotek Wireless to improve the applicability of their data storage technology to fishes, particularly salmonids. In 2014, beta-test archival tags (LAT4300) were implanted in 54 kelt released in the Campbellton River and the tags recovered are being studied for improving their data recording capabilities and geolocation algorithm. Eleven of these tags were designed to float, with the potential for retrieval should they wash ashore at some point. To date, 7 DSTs with data are being analyzed. To test improved attachment methods of DSTs for smolts, 100 smolts were tagged (tethered attachment method) with dummy DST tags also in 2014. One smolt was recovered ca. 5 weeks after release, with most expected to return in 2015.

Project Component 2 - Arctic char in their northern distribution

The Arctic charr work in Cambrdige Bay conclusively demonstrated the mixing of different stocks, which has important implications for fisheries management in the region.

7. Difficulties encountered

☒ Scientific problems/difficulties
☒ Personnel problems

Project Component 1 - Salmonids in the species transition zone

As noted earlier, we ran into severe ice conditions in Pistolet Bay that hindered the tagging of fish and the deployment of hydrophones. In 2015, we will return to Parkers Brook, Pistolet Bay, with the aim to tag fish during their outmigration (our 2014 data did provide information by which to gage this) and deploy hydrophone as soon as feasible in the Spring.

We also had difficulties in terms of the scheduled inclusion of students due to administrative time lags associated with the notification of the award and university deadlines for admission, particularly at U Waterloo. These difficulties were compounded by the immigration process, particularly as the student applications were made coincident with significant rule changes by the Federal Government. As a consequence, Kristin Bøe was not able to begin until May and Ingeborg Mulder not until September. Thus, only one of the PhD students could be involved in field work (receiver deployment, tagging and receiver down-loading) and we were heavily reliant on the invaluable support of our collaborators (DFO).

Project Component 2 - Arctic char in their northern distribution

No problems occurred during the reporting period.

8. Networking and outreach

a) *Intra-network collaboration and partner meetings*

Project Component 1 - Salmonids in the species transition zone

As noted above, collaboration to this point has been mainly limited to among the co-PIs and collaborators. There has been regular communication, as well formal meetings to discuss project design and progress (26 June 2013, 9 April, 17 June and 28 October 2014). We have also been in regular communication with Lotek wireless regarding the further development of DSTs for deployment of fishes, particularly salmonids.

Project Component 2 - Arctic char in their northern distribution

In December 2013, PDF Moore met with I. Bradbury, F. Whoriskey, and S. Iverson during the ArcticNet Annual Scientific Meeting in Halifax to discuss development with the Cambridge Bay work.

b) *Interaction/Outreach to Broader Community*

Project Component 1 - Salmonids in the species transition zone

We were successful in building on earlier results, and strengthening collaborations with local the angling community and with the NunatuKavut. We were quite particularly pleased with the level of local support and community interest at the Parkers Brook study site, which has produced great opportunities to utilize local media (newspaper) to increase awareness of our study.

Project Component 2 - Arctic char in their northern distribution

Interactions and communication continued with the community of Cambridge Bay. Regular e-mail exchange and phone conversation with the HTO management staff occurred throughout the year. In November 2013, PDF Moore attended a workshop in Cambridge Bay on community-based monitoring where strategies to more meaningfully involve the local community in OTN's work were discussed. Networking done at this event led to the development of a traditional knowledge study that is currently in the planning phase. During this visit, PDF Moore also visited the high school to give presentations in various classrooms. During the 2014, the President of the HTO was invited to observe the surgeries.

9. Dissemination of information and results

a) *Refereed journal articles (0 total) – accepted/published*
b) *Refereed journal articles (0 total) – submitted*
c) *Conference presentations (0 total) – invited*
d) *Conference presentations (1 total) – contributed*

Moore, J. -S., Harris, L. N., Tallman, R. F., and Fisk, A. (2013) Migratory behaviour of anadromous Arctic char in the Cambridge Bay region. ArcticNet Annual Scientific Meeting, December 2013, Halifax, Canada.

10. Other contributions and deliverables

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

Fleming, I. A. (2013) Behaviour of Atlantic salmon at sea. Labrador Institute, November 2013, Goose Bay, Canada (invited).

g) Data deposition to OTN Data Centre

Deposition of tagging information regarding Arctic charr and Atlantic salmon.

h) Invited or contributed consultation with an agency; public or private

Collaborative consultation with Lotek Wireless in the further development of DSTs for deployment on fishes, particularly salmonids.

k) Internet publishing, portal, blog, electronic publications

YouTube (Lotek Wireless) - "Fish-friendly attachment method for long term deployment of geolocation tags" (> 1,500 hits)

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

Newspaper articles:

Northern Pen (St. Anthony, Newfoundland). "Tagged char and salmon now being monitored." 22 July 2013.

Northern Pen (St. Anthony, Newfoundland). "Monitoring movements." 25 July 2014.

Videos:

Northern Pen (St. Anthony, Newfoundland). "Western Brook char." 25 July 2014 - http://www.northernpen.ca/Video/33737/Western-Brook-char

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 collaborators 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. We also collaborate with Lotek Wireless on refining the use of DSTs for deployment on fishes, particularly salmonids.

Project Component 2 - Arctic char in their northern distribution

…

b) Contributions

Name of supporting organization: **DFO, Newfoundland and Labrador Region**	**Year 5** (2014)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
25) Salaries for scientific and technical staff	31000
26) Donation of equipment, software	26000
27) Donation of material	
28) Field work logistics	15000
29) Provision of services	
30) Other (specify): travel	10000
In-kind contributions to indirect costs of research	
13) Use of organization's facilities	10000
14) Salaries of managerial and administrative staff	4000
15) Other (specify):	
Total of all in-kind contributions	96000
Is this new funding (acquired during this reporting period)?	yes

Name of supporting organization: **Save our Charr Committee (SOCC)**	**Year 5** (2014)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
19) Salaries for scientific and technical staff	
20) Donation of equipment, software	
21) Donation of material	
22) Field work logistics	4000
23) Provision of services	
24) Other (specify):	
In-kind contributions to indirect costs of research	
10) Use of organization's facilities	
11) Salaries of managerial and administrative staff	
12) Other (specify):	
Total of all in-kind contributions	4000
Is this new funding (acquired during this reporting period)?	yes

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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

The summer of 2014 marked the third field season of research in Resolute Bay, Nunavut. Overall, the season was a success, with all but three research goals achieved. All research equipment deployed during the 2013 field season was successfully recovered and found to be in working order. All data was successfully downloaded and all equipment was maintained and redeployed as intended. All 30 intended sculpin were captured tagged and released in good condition, while a further 30 were sacrificed for biological samples. Six Greenland sharks where captured for genetic and blood sampling, three of which were acoustically tagged and released in good condition. Unfortunately, Arctic cod were not present in the research area this year, confirmed by >170 hours of searching with a fish finder, meaning we were unable to tag or sample any specimens of that species. Netting efforts for ringed seals were also unfruitful, thus the three remaining seal tags could not be deployed. All intended oceanographic sampling was conducted. Due to favourable weather conditions throughout, several more replicates than intended were possible. A meeting with the Resolute Bay HTA was held to discuss results to date and future research. The meeting was very positive and beneficial for our research and relationship with the local community. A town meeting was held to discuss OTN research in the region and to explore community request for a documentary film being developed by HQP Silviya Ivanova. The community appeared to be excited by the prospect and have proceeded to give permission for on camera appearances. Some of which were able to be filmed in the 2014 field season. The research team was able to coordinate with the Qarmartalik School to perform live tagging and dissections of sculpin for several science classes. Finally a second trip was made to the Lancaster Sound region aboard the Kiviuk fishing vessel in an attempt to retrieve the receiver line near Maxwell Bay. Unfortunately, due to schedule delays prior to boarding, ice formation prevented access to the mooring locations.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Steven Kessel	RA	100	100	1-Jan-2012	30-Jun-2016

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Research Topic: Movements of fish species in the high Arctic					
David Yurkowski	PhD	100	50	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 new field experience on board a large commercial fishing vessel and continues firearms training.

David Yurkowski – lead for seal tagging program. David was in charge of all fieldwork activities related to the ringed seal study. These included setting/retrieving/maintaining seal nets. David also participated in additional research activities including oceanographic sampling, fish capture and tagging, acoustic telemetry retrieval and deployment and plankton tows. During this research year David participated in two state-space modelling workshops, gained vital vessel experience, and continued firearms training.

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 seal netting, fish capture and tagging, acoustic telemetry retrieval and deployment and plankton tows. During this research year Caitlin gained, gained vital 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 took firearms and vessel training, gained vital vessel experience and active firearms training. Additionally he was trained in various aspects of acoustic telemetry research, including monitor mooring set up, deployment, recovery and maintenance, and data download and interpretation.

Silviya Ivanova – MSc student focussing on anthropogenic disturbances to 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. Silviya also set up a time-laps camera overlooking the bay to quantify vessel traffic and ice dynamics over the coming year. During the research year, Silviya took

firearms and vessel training, gained vital 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.

6. Progress towards objectives/milestones

a) Overall objectives

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) Investigate the relationship between beluga hunting and Arctic cod and sculpin behaviour;

g) 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);

h) 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

Objective a) to date, 85 Arctic cod and 75 sculpin have been acoustically tagged. One full year of Arctic cod and two 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 and data analysis is currently underway.

Objective c) tissues and stomach contents have been collected from >100 Arctic cod and >200 sculpin. 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. Two years of 180 KHz data at a course scale has been processed, and a high resolution detection range test deployed for four different tag types.

Objective e) Satellite transmitters have been deployed on 7 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. A scientific note that will be submitted to Marine Mammal Science is nearly complete, which details the longest unidirectional movement for a ringed seal ever recorded.

Objective f) to date three years of echolocations click data has been collected from marine mammals in the region. This will be compared to acoustic tracking data to test the influence of marine mammal presence of fish behaviour.

Objective g) to date eight Greenland sharks have been acoustically tagged in the Resolute Bay area and a 12 have been sampled for genetics and stable isotopes.

Objective h) two years of oceanographic profiling data and three 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. This data is currently being used for a manuscript under preparation.

c) Significant deviations

Objective a) following great success in 2012, no Arctic cod were encountered during the 2013/14 seasons and thus it was not possible to tag or sample any.

The inability to find and tag Arctic Cod in 2014 was a setback for the project 4.10 objectives to study the environmental fish interactions in the high Arctic environment. However, this project will still meet these objectives because:

- we have a full year of Arctic Cod acoustic data in Resolute Bay from 2012-2013 that has resulted in a recent journal submission on the impact of environmental variables on Arctic cod behavior and movement (Kessel, S.J., N.E. Hussey. R. Crawford, C.V. O'Neill, D.J. Yurkowski and A.T. Fisk. 2014. Environmental conditions associated with Arctic cod (Boreogadus saida) presence and absence in a high Arctic embayment revealed through acoustic telemetry. Polar Biology Submitted Dec 21, 2104)

- the 2012-2013 Arctic Cod data also includes VPS which will be a second publication on specific behaviors

- we have compiled all of the Arctic Cod telemetry data for 2010 collected for Allen Bay (just east of Resolute Bay) by former PI Terry Dick. In fact, we had PI Dick's former OTN MSc student (Jordan Matley) at Windsor in December and met with him to confirm details about the data and project. Jordan will collaborate on publishing this data, which will be used by MSc students Ivanova and Landry and includes Arctic Cod, Sculpin, VPS and oceanography data.

- we will have 3 years (2012-2015) of data on tagged sculpin (2 species) from Resolute Bay and 1 year from Allen Bay for MSc Landry's research.

- we will have 3 years (2012-2015) of stable isotope data for Resolute Bay that includes invertebrates and marine mammals

- former MSc student Jordan Matley has published 4 papers related to Arctic Cod in Resolute Bay.

Objective e) Following the succes of 2013 where 4 seals were successfully captured and deployed with transmitters, no seals were captured in 2014. Fewer ringed seals were observed in 2014 compared to 2012 and 2013.

The inability to satellite tag ringed seals in 2014 was also a small setback for this project. However, 7 seals were previously tagged in this region, which resulted in a paper submission in late November (Yurkowski, D.J., S. Clackett, A. Gragicak-Mannion, S.H. Ferguson and A.T. Fisk. 2014. An Arctic odyssey: unexpected long-distance movements and deep dives by an adult male ringed seal (Pusa hispida) revealed by satellite telemetry. Animal Biometry Submitted November 27, 2014). Importantly, PhD student Yurkowski has compiled satellite data from more than 130 ringed seals from throughout the Canadian Arctic and Greenland, easily the most comprehensive such data set for ringed seals and arguably arctic marine mammals. Analysis of this massive data set has progressed very well and we anticipate multiple high level publications on the impact of environmental conditions on the movement and behavior of ringed seals.

Objective g) ice conditions prevented the retrieval of the acoustic stations adjacent to Maxwell Bay. This are anticipated to contain crucial data for determining the movements and timing of Greenland sharks in the high Arctic. These stations will be recovered in the 2015 open water period.

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 2014. 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 S. Dufault on deployment and data acquisition by the CTDs 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 including meeting between A Fisk and D. Webber in Halifax and Windsor. PhD student Dave Yurkowski has had numerous discussions with Drs. Steve Ferguson (DFO – Winnipeg) Becky Sjare (DFO – St. John's) and Tanya Brown (PhD candidate – University of Victoria) about improving the technique to live-capture ringed seals.

e) Scientific and/or engineering significance

The detection range test deployed in Resolute Bay represent the most comprehensive tests in terms of 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). 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.

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.

7. Difficulties encountered

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

Scientific problems/difficulties – The main scientific problem encountered this research year was the complete absence of Arctic cod from the Resolute Bay region for a second year running. It was assumed in 2013 that the absence was the result of abnormal climatic conditions. However, the climatic conditions in 2014 were more typical and Arctic cod were still not present. This indicates that Arctic cod presence is not guaranteed year to year in the Resolute Bay area. In addition, fewer ringed seals were observed in 2014 compared to previous years, which lead to no seal capture. Finally, due to a delayed schedule, ice conditions prevented the retrieval of the acoustic stations deployed near Maxwell Bay. These moorings will be recovered in the 2015 open water period.

Equipment issues – We had two Edgetech deck boxes stop working during the field season and a replacement unit had to be sent. Despite this issue all moorings were recovered successfully.

Personnel problems – During the 2014 field season, MSc student Justin Landry developed appendicitis. As such it was necessary for him to fly to Iqaluit to have his appendix removed. The operation was a success, but as a precaution his field season was cut short and he was sent back to Windsor to recover.

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 in Ottawa. 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 and Nigel Hussey were involved in the development of the OTN False detection filtering tool. The group has been seeking the assistance of Montana McLean (of the Pacific Arena) to aid in the processing of VPS data. David Yurkowski has taken part in two state-space modelling workshops led by Joanna Mills-Flemming. He is collaborating with Kim Whoriskey, Joanna Mills-Flemming (both of Atlantic Arena), and Anders Nielsen and Cristoffer Moesgaard-Albertsen (Technical University of Denmark) by comparing different state-space model analyses using a newly developed R package (TMB) and function (ArgosTrack) via ringed seal movement data. During the Ottawa OTN Symposium, HQP Caitlin O'Neill met with the other OTN oceanographers to discuss collaborative potential across arenas, and specifically in relation to the processing of Benthic Pod data. Finally, HQPs Nigel Hussey and Steven Kessel and PI Aaron Fisk were involved in the production of a telemetry review paper that is currently in review in the journal 'Science'.

b) Interaction/Outreach to Broader Community

During the 2014 field season, a meeting was held with the Resolute Bay Hunters and Trappers Association (HTA). During this meeting the results of the study to date were presented to the HTA committee and then discussed in context to their traditional knowledge as a group. A public town meeting was held and open to members of the Resolute Bay community. The results of the study were presented to the community and discussed in relations to past and present research directions. 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 hosted several classes from the local school, to talk about the OTN research and perform some live tagging/ dissections in the science class. David Yurkowski attended a national ringed seal monitoring workshop which hosted several hunters from different communities as well as numerous university and governmental agencies. He presented preliminary results of all (n=130) ringed seal movement tracks from different Arctic locations, which was of great interest to all attendees.

9. Dissemination of information and results

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

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

b) Refereed journal articles (2 total) – submitted

Hussey, N. E., Kessel, S. T., Aarestrup, K., Cooke, S. J., Cowley, P. D., Fisk, A. T., Harcourt, R. G., Holland, K. N., Iverson, S. J., Kocik, J. F., Mills Flemming, J. E., and Whoriskey, F. G. (2014) Aquatic animal telemetry across diverse scales: discovery, applications and relevance. Science Submitted Sept 23, 2014

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

c) Conference presentations (0 total) – invited

N/A

d) Conference presentations (6 total) – contributed

Kessel, S. T., Hussey, N. E., Vagle, S., Crawford, R., Ferguson, S., and Fisk, A. T. (2014) Residency and distribution of Arctic cod (Boreogadus saida) in Resolute Bay, Lancaster Sound. OTN Symposium, June 2-5, Ottawa, Canada.

Yurkowski, D. J. et al. (2014) Spatial variation in ringed seal (Pusa hispida) foraging behaviour across the Arctic. 4th Ocean Tracking Network Symposium, June 2-5, Ottawa, Ontario. Oral presentation.

Yurkowski, D. J. et al. (2014) Movements and foraging habits of ringed seals across the Arctic. National Ringed Seal Monitoring Workshop, March 2014, Iqaluit, Nunavut. Oral presentation.

Yurkowski, D. J. et al. (2013) Movements and foraging habits of an ice-adapted predator in the Arctic. 20th Biennial Conference on the Biology of Marine Mammals, December 2013, Dunedin, New Zealand. Oral presentation.

O'Neill, C. (2014) Oceanography and Acoustics Research in Resolute Bay, Nunavut. 4th Ocean Tracking Network Symposium, June 2-5, Ottawa, Ontario. Oral presentation.

Ivanova, S., Kessel, S. T., Fisk, A. T., and Nelson, K. (2014). Arctic cod school occurrence and behaviour related to boat traffic and presence of predators. OTN Symposium, June 2-5, Ottawa, ON, Canada.

10. Other contributions and deliverables

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

Steven Kessel. Canada's Rogue Shark. Discovery Channel. Shark Week

David Yurkowski. University of Windsor - Research Matters Radio Show

c) Invited or contributed presentation/contribution at a workshop

Kessel, S. T., Bajona, L. T., Cooke, S. J., Halfyard, E. A., Heupel, M. R., Hussey, N. E., Jones, B. L., Mihoff, M., Simpfendorfer, C. A., Vagle, S., Webber, D., White, E. R, and Fisk, A. T. (2014) Detection range testing and dealing with false detections. GLATOS Workshop. Ann Arbor, MI, USA.

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

Yurkowski, D. J. (2014) Resource-use specialisation and the feeding ecology of an ice--adapted predator in a changing Arctic ecosystem. Freshwater Institute – Fisheries and Oceans Canada, Winnipeg, Manitoba. Invited Seminar, January 2014.

g) Data deposition to OTN Data Centre

Pending

k) Internet publishing, portal, blog, electronic publications

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

o) 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

OTN Detection Filtering Tool (HQPs Steven Kessel and Nigel Hussey).

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: **JASCO Applied Sciences**	**Year 5** (2014)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
31) Salaries for scientific and technical staff	
32) Donation of equipment, software	$20,000
33) Donation of material	
34) Field work logistics	
35) Provision of services	
36) Other (specify):	
In-kind contributions to indirect costs of research	
16) Use of organization's facilities	
17) Salaries of managerial and administrative staff	
18) Other (specify):	
Total of all in-kind contributions	$20,000
Is this new funding (acquired during this reporting period)?	yes

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

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

Projects in the Baffin Island area were very successful as the second year of data from the acoustic receivers in Scott Inlet and Sam Ford Fjord were collected with numerous detections from tagged Greenland halibut and Greenland sharks. Greenland halibut are one of the most important commercial species in the Arctic Ocean, with interest in many communities of developing artisanal Inuit fisheries for these deepwater species, however much remains unclear about their movement patterns to dictate proper management. This is also true for the primary bycatch species associated with the Greenland halibut fishing industry, the Greenland shark, which is an environmentally important top predator in the Arctic ecosystem. In addition to adding further moorings to the system along with tagging additional fish, a couple smaller Greenland sharks were equipped with satellite tags that will record fine scale depth and temperature information throughout the year to provide information on these juveniles that are so rarely captured anywhere else in the Arctic. Oceanographic instruments were recovered, and smaller temperature and depth sensors deployed this year throughout the system in order to model the relationship between the environment and benthic fish habitat use. A deep sea AURAL (for monitoring marine mammals) as well as an acoustic receiver were deployed at the entrance to Clyde Inlet to investigate the connection between marine mammal populations and Greenland sharks as data suggests the sharks may follow whales along the Baffin Island coast. Genetic samples were also collected from all captured Greenland halibut and sharks in order to better understand the population structure of these species in the Arctic system and how potential sub-populations may explain variability in the movement and migration patterns observed in the tagged fish. Work in Cumberland Sound has resumed, with the deployment of new acoustic monitors as well as the tagging of more Greenland halibut and Greenland shark. This will provide additional data to interested parties to justify moving the existing management boundary that divides the inshore artisanal Inuit fishing area from offshore vessels.

5. Training of Highly Qualified Personnel

a) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Jeannette Bedard	PhD	100	100	Sept-2011	Dec-2015
Research Topic: Physical Oceanography and Acoustics in Cumberland Sound and Scott Inlet					
Nigel Hussey	RA	100	25	1-Jan-2010	30-Jun-2016
Research Topic: Deep water arctic marine fish movements					
Marianne Marcoux	PDF	10	0	1-Jun-2010	Aug-2014
Research Topic: Movement, feeding behaviour and feeding ecology arctic whales					
Amanda Barkley	MSc	100	100	1-May-2013	Apr-2015
Research Topic: Greenland Halibut					
Natalie Reinhart	PhD	100	100	1-Jan-2014	31-Dec-2014
Research Topic: Killer whale predation in the eastern Canadian Arctic					

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. Specifically, advanced HQPs such as PDF Hussey are involved in training students (such as MSc Barkley) in the procedures for capturing and tagging Greenland halibut, servicing acoustic monitors and deploying moorings.

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, marine mammals and Greenland sharks;

4) To quantify larger system-system movements of Greenland halibut tagged in Cumberland Sound 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 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.

b) Progress

1) The acoustic array (70 – VR2W-69), oceanographic equipment (2 stations) and marine mammal listening devices (4 CPODs and 1 AURALs) were successfully retrieved this year and the data offloaded from the devices. Over 22,000 detections were recorded on the recievers from 94 individual fish (Greenland sharks and Greenland halibut). There is now more data to elaborate on the seasonal trends seen last year, and a preliminary assessment suggests that smaller Greenland halibut may use this area as a transitory feeding ground, and larger individuals are more sedentary.

2) All acoustic receivers were redeployed along with an additional 10 moorings that have been added to the system. Two AURALS (one deep sea, and one shallow) were also deployed along with small temperature depth sensors to monitor the deep sea system.

2) A total of 72 Greenland halibut and 23 Greenland sharks were internally tagged with various V16 and V13 acoustic tags this year, increasing the total number of tagged fish in this system to 168 Greenland halibut, and 59 Greenland sharks.

3) Two juvenile Greenland sharks 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.

4) An additional 12 trawls between depths of 200-800m were undertaken throughout Scott Inlet and a suite of species sampled for examining food web structure and trophic interactions tied with acoustic telemetry data. Specifically, many Arctic cod were captured; a keystone species in this environment that is important for understanding the foodweb structure.

5) More stress measures for deep water Arctic species were undertaken through the use of lactate, glucose, and this year the addition of cortisol samples for Greenland halibut. Samples were taken from acoustically tagged fish to look at survival, as well as the recovery profile of Greenland halibut

captured on a longline was examined. This work is in conjunction with PI Cooke to better understand survival and stress in these little known arctic species.

6) Following 2 years (2010-2012) of highly successful acoustic telemetry work on Greenland Halibut, Arctic Skate and Greenland shark in Cumberland Sound, the Pangnirtung Hunters and Trappers Association (HTA) would not support continuation of the project. HTA approval of all research is required for DFO and Government of Nunavut (GN) permits necessary for research in Nunavut. The HTA was acting on concern from the community that acoustic receivers placed in Cumberland Sound were scaring away seals and whales. Despite community presentation by PI Fisk and DFO scientists, and support from the GN and Pangnirtung commercial fishermen, the community would not approve continuation of the project. All OTN and GN acoustic telemetry equipment was moved to Scott Inlet (west coast of Baffin) to continue work on this species with full support from the local community of Scott Inlet.

   The OTN research in Cumberland Sound was specifically designed to address management issues of Greenland Halibut stocks, namely if fish caught in the Inuit controlled winter fishing grounds were the same stock as those available to commercial fishing vessels in the summer fishing grounds. Our initial research results provided support for that the Halibut in Cumberland Sound was a single stock, which would help the Inuit fishermen from Pangnirtung protect this resource from exploitation from large commercial fishing vessels. Indeed, the community and HTA used our data to petition DFO and international bodies to make all of Cumberland Sound protected and under the control of the local community of Pangnirtung. This petition was rejected because there was only a single year of data. After consultation with DFO, the community recognized that acoustic telemetry research was the quickest way to generate sufficient data to support their petition and they approved a new deployment of receivers (n = 15) and tags in 2014 in Cumberland Sound. The community provided feedback on receiver placement during a trip to the community in May 2014 by OTN-PI and DFO scientists Kevin Hedges, mainly requesting that receivers not be placed in prime winter fishing grounds. The research will continue until at least 2016, with significant GN and DFO support. Details on 2014 work (location of moorings and number of fish tagged) have already been communicated to the community and expansion of the array, particularly into newfound deep spots in the winter fishery grounds.

c) Significant deviations

There were no significant deviations from the original objectives or plans in the tagging component of the Scott Inlet region.

e) Scientific and/or engineering significance

The results of the Baffin Island projects may have a significant effect on the communities in the Arctic as well as influancing how we manage commercially important deepwater Arctic species. The data from Scott Inlet suggests that many of the smaller Greenland halibut (<55 cm) that were tagged use this area as a transitory feeding ground, as they are present during open ice periods and frequently have large, distended stomachs filled with Arctic cod when caught. In the winter months these smaller individuals then move back out into Baffin Bay, while tagged larger fish (>55 cm) stay in the system, occasionally moving further into the fjords. As the local community of Clyde River has expressed an interest in developing a fishery for Greenland halibut, this information will be useful to target fish of an appropriate size for a commercial industry, most likely centered around fishing in the winter, through the ice. This will also provide both the Government of Nunavut and DFO with important informatio on

the highly mobile nature of young Greenland halibut that may be more heavily implicated in population connectivity between the multiple fishing areas. This connectivity is also continuously being examined by taking genetics samples from all captured fish to better understand the population dynamics seen in this species.

The Scott Inlet/Sam Ford Fjord system has also proven to be a unique location to capture juvenile Greenland sharks which have not been regularly caught in any other area of the Arctic before. This provides scientific information that has rarely been accessable as acoustic and satalite tagging of these small sharks provides data on their locations and habitat preference. A shark tagged in 2012 that had left the system within the fist month after tagging did return this past year, suggesting some level of site fidelity to this area. Further analysis is requred to continue investigating the hypothesis that the Greenland sharks are following the marine mammals through this area as this will give great insights into the biology of these animals and provide better understanding of their migratory nature.

The continued stress research of both Greenland halibut and Greenland shark has also provided insights into these little known species, as values remained similar to those collected in the first year, however slightly lower in the sharks. By collecting blood samples from tagged fish, a look at survial in these species can be conducted concurently with the tracking study. Greenland halibut were also held for 24h to examine the recovery profile of this species to determine how long relesed fish require before returning to a normal homiostatic state after release.

7. Difficulties encountered

☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)

Equipment and technology issues: This year we were unsuccessful in recovering one of our moorings, most likely caused by the battery in the acoustic release becoming too low to power the motor. Communications with the release were successful (however the signal was weak) but when commanded to release, it would not respond. We tried multiple times to recover the mooring, however we were never successful. Secondly, we had intended to use the bottom trawl on the Nuliajuk in order to capture benthic species for food web analysis and abundance estimates, as well as Greenland halibut for tagging, however on the second day of trawling the clutch on the boat broke, and the logistics of getting it fixed in a reasonable timeframe were not possible. We therefore used available longlines to capture Greenland halibut, and we were still successful in meeting our goals for the total number of tagged fish released this year.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

In June 2014, the OTN Symposium in Ottawa allowed for a venue to meet and disscuss tracking results and establish plans and ideas between fellow Arctic researchers as well as those in other areans. The work with Pacific Arena PI, Dr. Steven Cooke has continued this year to look at capture related stress levels in deepwater Arctic species, and we have expanded this objective to also look at survival of tagged fish and how this correlates with stress parameters. PhD Bedard also provided valuable data on average temperatures in the Scott Inlet system from CTD casts to MSc Barkley and PDF Hussey for the stress analysis of Greenland halibut and Greenland sharks.

b) Interaction/Outreach to Broader Community

Meetings with the Clyde River HTO were held once again this year in order to obtain approval for the work in Scott Inlet. This invovled a disscussion about what the work intails as well as a brief overview of current results. At the end of the field work, PDF Hussey was invited to talk on the local radio station in Clyde River about the work being conducted in Scott Inlet. This allowed any residents in the community to call in and ask questions or voice any concerns. This turned out favorably, and allowed local residants to contribute thoughts, ideas and local knowledge to the project. Email contact with Dr. Neil Hammerschlag has also lead to interest in looking at triglyceride levels in the Greenland sharks as a possible measure of the shark's condition level, and how this may be associated with migration patterns.

9. Dissemination of information and results

a) Refereed journal articles (7 total) – accepted/published

Yurkowski, D. J., Hussey, N. E., Semeniuk, C., Ferguson, S. H., and Fisk, A. T. (2014) Effects of chemical lipid-extraction and the utility of lipid-normalization models on stable isotope values in arctic marine mammal tissues. Polar Research (In press).

Peklova, I., Hussey, N. E., Hedges, K. J., Treble, M. A., and Fisk, A. T. (2014) Movement, depth and temperature preferences of an important bycatch species, Arctic skate (Amblyraja hyperborea) in Cumberland Sound, Canadian Arctic. Endangered Species Research 23:229-240.

Hussey, N. E., MacNeil, M.A., McMeans, B. C., Olin, J. A., Dudley, S. F. J., Cliff, G., Wintner, S. P., Fennessy, S., and Fisk, A. T. (2014) Rescaling the trophic structure of marine food webs. Ecology Letters 17: 239-250.

Kessel, S. T., Cooke, S. J., Heupel, M. R., Hussey, N. E., Simpfendorfer, C. A., Vagle, S., and Fisk, A. T. (2014) A review of detection range testing in aquatic passive acoustic telemetry studies. Reviews in Fish Biology and Fisheries. 24: 199-218.

Cooke, S. J., Nguyen, V., Murchie, K. J., Thiem, J. D., Donaldson, M. R., Hinch, S. G., Brown, R. S., and Fisk, A. T. (2013) To tag or not to tag: Animal welfare, conservation and stakeholder considerations in fish tracking studies that use electronic tags. Journal of International Wildlife Law & Policy.

Peklova, I., Hussey, N. E., Hedges, K. J., Treble, M. A., and Fisk, A. T. (2012) Depth and temperature preferences of the deepwater flatfish, Greenland halibut (Reinhardtius hippoglossoides) in an Arctic marine ecosystem. Marine Ecology Progress Series 467: 193-205.

Marcoux, M., McMeans, B. C., Fisk, A. T., and Ferguson, S. H. (2012) Composition and temporal variation in the diet of the threatened population of belugas in Cumberland Sound. Marine Ecology Progress Series 471: 283–291.

b) Refereed journal articles (2 total) – submitted

Hussey, N. E., Kessel, S. T., Aarestrup, K., Cooke, S. J., Cowley, P. D., Fisk, A. T., Harcourt, R. G., Holland, K. N., Iverson, S. J., Kocik, J. F., Mills Flemming, J. E., and Whoriskey, F. G. (2014)

Aquatic animal telemetry across diverse scales: discovery, applications and relevance. Science Submitted Sept 23, 2014.

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. (2014) Juvenile and sub-adult Greenland shark Somniosus microcephalus (Bloch & Schneider, 1801) in the Canadian Arctic. Polar Biology (In revision).

c) Conference presentations (1 total) – invited

Fisk, A.T. (2013) The Ocean Tracking Network: A global system to quantify and track the movement of marine animals and their environmental correlates. Keynote Presentation, ArcticNet Meetings, Halifax, NS, Dec 12, 2013.

d) Conference presentations (3 total) – contributed

Barkley, A. N., Hussey, N. E., Hedges, K., Ferguson, S., Vagle, S., Treble, M., Fisk, A.T. (2014) Movements of the deepwater flatfish, Greenland halibut in the coastal fjords of Baffin Island. OTN Halifax Symposium. Oral presentation.

Bedard, J. M., Vagle, S., Klymak, J., Williams, W. (2013) Physical Oceanography of Cumberland Sound, Baffin Island. ArcticNet Meetings, Halifax. Oral Presentation.

Bedard, J. M., Vagle, S., Klymak, J., Williams, W. (2014) Origins of the deep water in Cumberland Sound, Baffin Island. OTN Symposium, Ottawa. Oral Presentation.

10. Other contributions and deliverables

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

October 7, 2014: PDF Hussey was interviewed by the local radio station in Clyde River about the research in Scott Inlet and Sam Ford Fjord.

May 9-12, 2014: MSc Barkley travelled to Arctic Bay, Nunavut to meet with a film crew from the BBC that were filming a documentary on sharks, with a segment on Greenland sharks, in order to disscuss capture related stress on these animals.

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

Barkley, A. N., Cooke, S. J., Fisk, A. T., Hedges, K., and Hussey, N. E. (2014) Capture Induced Stress in a Deep-water Marine fish and the Implications for the Release of by-catch in the Arctic. 2014 GLIER Multidisciplinary Graduate Student Symposium, Windsor, Ontario. Oral presentation.

11. Collaborations with industrial and government partners

b) Contributions

Name of supporting organization: **Government of Nunavut - CANor Inshore Funding**	**Year 5** (2014)
Cash contributions to direct costs of research	$194,900
In-kind contributions to direct costs of research	
37) Salaries for scientific and technical staff	
38) Donation of equipment, software	
39) Donation of material	
40) Field work logistics	
41) Provision of services	
42) Other (specify):	
In-kind contributions to indirect costs of research	
19) Use of organization's facilities	
20) Salaries of managerial and administrative staff	
21) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **DFO**	**Year 5** (2014)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
25) Salaries for scientific and technical staff	
26) Donation of equipment, software	$128,350
27) Donation of material	
28) Field work logistics	$353,000
29) Provision of services	
30) Other (specify):	
In-kind contributions to indirect costs of research	
13) Use of organization's facilities	
14) Salaries of managerial and administrative staff	
15) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Northern Science Training Program**	**Year 5** (2014)
Cash contributions to direct costs of research	$2,500
In-kind contributions to direct costs of research	
13) Salaries for scientific and technical staff	
14) Donation of equipment, software	
15) Donation of material	
16) Field work logistics	
17) Provision of services	
18) Other (specify):	
In-kind contributions to indirect costs of research	
7) Use of organization's facilities	
8) Salaries of managerial and administrative staff	
9) 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 5 Review: 1 October 2013 – 30 September 2014

1. Project Numbers: 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 several hundred sockeye salmon smolts in an effort to identify where 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 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. The work conducted in 2013-2014 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	End Date
Eduardo Martins	RA	100	100		1 Oct 2013	30 Nov 2014
Research Topic: Modeller/analyst involved with numerous OTN projects						
Doug Braun	PDF	10	0	BCHydro	1 June 2011	On-going
Research Topic: PIT tag assessments of Seton River salmon behaviour						
Erika Eliason	PDF	25	0	NSERC PDF	1 Jan 2011	On-going
Research Topic: Adult salmon thermal tolerance and survival						
Mike Donaldson	PDF	25	0	NSERC PDF	1 Sept 2012	30 Sept 2014
Research Topic: Adult salmon capture/release and stress studies						
Ken Jeffries	PDF	5	0	Cal.State PDF	1 Jan 2012	30 Sept 2014
Research Topic: Genomics and migration success in Pacific salmon						
Wenming Zhang	PDF	25	0	BCHydro	1 Aug 2013	On-going
Research Topic: ADCP assessments of river hydraulics						
Mandy Banet	PDF	10	0	NSF	1 Sept 2012	On-going
Research Topic: Stress effects on juvenile salmonids						
Katrina Cook	PhD	100	20	NSERC PGSD UBC Fellowship	1 Sept 2012	On-going
Research Topic: Adult salmon capture/release marine studies						
Amy Teffer	PhD	30	0	NSERC Strategic UVic Fellowship	1 Sept 2011	On-going
Research Topic: Effects of handling and temperature on salmon disease and survival using laboratory experiments						
Arthur Bass	PhD	100	0	NSERC Strategic UBC Fellowship	1 Sept 2012	On-going
Research Topic: Effects of handling and temperature on salmon disease and survival using telemetry studies						
Matt Drenner	PhD	100	100		1 Sept 2009	On-going
Research Topic: Relationships between oceanographic conditions and adult salmon migration timing, survival and physiology						
Graham Raby	PhD	100	0	NSERC PGSD	1 Oct 2013	30 Dec 2014
Research Topic: Effects of capture/release fisheries on salmon migration behaviour, physiology and RAMP						
Nolan Bett	PhD	30	0	NSERC PGSD UBC Fellowship	1 Sept 2011	On-going

Name	Title	% Time in project	% Support from OTNC	Sources of other support	Start Date	End Date
Research Topic: Factors affecting olfaction and homing success in adult salmon						
Natalie Sopinka	PhD	10	0	NSERC PGSD UBC Fellowship	1 Jan 2009	On-going
Research Topic: Effects of stress on survival and fitness of adult salmon						
Nathan Furey	PhD	100	20	UBC Fellowship	1 Sept 2011	On-going
Research Topic: Modelling survival and behaviour of outmigrating salmon smolts						
Vivian Nguyen	PhD	10	0	NSERC PGSD	1 Jan 2014	On-going
Research Topic: Social science perspectives on telemetry and fisheries capture/release						
Montana McLean	PhD	100	100		1 Jan 2014	On-going
Research Topic: Tracking white sturgeon using telemetry						
Nich Burnett	MSc	100	0	BCHydro	1 Sept 2011	30 Oct 2014
Research Topic: Using physiological and accelerometry telemetry to examine migration success in adult salmon						
Vaness Minke-Martin	MSc	100	0	NSERC PGSM	1 Sept 2013	On-going
Research Topic: Role of thermal refugia in migration and spawning success in adult salmon						
Melissa Dick	MSc	100	0	OGS	1 July 2014	On-going
Research Topic: Assessing effects of different tagging and handling on migration and spawning success in adult salmon						
Marianne Corriveau	MSc	20	0	U Ottawa	1 Oct 2013	30 Sept 2014
Research Topic: Using knowledge mobilization theory to better determine how to integrate telemetry information into management						
Cassandra Story	BSc	100	30	NSERC Discovery	1 Jan 2014	On-going
Research Topic: No research topic – just research assistant						
Taylor Ward	BSc	20	0	NSERC Discovery	1 Aug 2014	30 Sept 2014
Research Topic: No research topic – just research assistant						
Petra Szekeres	BSc	100	50	NSERC Strategic	1 July 2014	30 Dec 2014
Research Topic: No research topic – just research assistant						
Stephen Healy	BSc	25	25	NSERC Discovery	1 Sept 2012	On-going
Research Topic: No research topic – just research assistant						
Neil Fowler	BSc	100	25	NSERC Discovery	1 Sept 2014	30 Dec 2014
Research Topic: No research topic – just research assistant						
Laura Elmer	BSc	100	0	UK Fellowship	1 Sept 2014	30 Nov 2014
Research Topic: No research topic – intern from UK						

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) 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. 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. Our technical staff serve 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.

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 Pacific and Atlantic 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 and sockeye. Several papers were submitted/published in 2014 examining survival rates following beach seine, gillnet, trap box, 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.

Using social science survey methods, in conjunction with the tagging and RAMP studies, First Nations fishers were interviewed to gain an understanding of how they viewed telemetry and recovery research, how they feel it should be used to help them manage their fisheries resource and the threats and opportunities they face in regards to their fisheries. The primary findings were that over 2/3rd of First Nations fishers trusted the results of telemetry science and felt positively about how it could help fisheries management. A majority felt that recovery bags were a good idea to implement and would do so themselves if bags were shown to be helpful for salmon survival. We have also recently completed a series of surveys of fisheries managers and others in positions of authority in regards to the salmon fishery in order to better assess how results from capture/release research can better be integrated in management and policy frameworks. These results are pending.

In summer/fall 2014, we conducted three field studies involving tagging and releasing > 700 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 (e.g. pathogen loads) as predictors of release and delayed mortality. These studies utilized the POST/OTN acoustic receiver lines, the lower Fraser River array (Kintama partner line), and acoustic and radio receivers temporarily located in several sub-basin

watersheds of the Fraser River. Data downloads from the POST/OTN lines and lower Fraser River will occur in November 2013.

In summer/fall 2014, laboratory experiments were conducted at UBC and the DFO Cultus Lake Laboratory examining the effects of capture stress and release (e.g. capture/release from a gillnet) on adult sockeye physiological recovery, pathogen load development 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. In 2014 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.

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 initiated 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

The fieldwork for this study began in mid-October 2014 and is currently in progress.

4.14 Seasonal movements and spawning migrations of white sturgeon

Through partnering with a recreational fishing guide, we sampled 64 adult white sturgeon from the catch and release fishery. All fish had a blood sample taken to measure stress hormones, and 28 were 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. In May 2014 we supplemented the array with an addition 16 acoustic receivers so as to increase coverage in key areas where spawning activity is known to occur

(near Chilliwack). We also conducted preliminary 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 preliminary results are showing strong direct correlations between RAMP and glucose and lactate levels in blood plasma. Future 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 and Atlantic salmon

Summarization and write-up of results from outmigrating smolt studies from 2010 to 2014 have been ongoing and resulted to date in several technical reports and recently accepted manuscripts. In 2014 spring, 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. In April and May 2014, acoustic transmitters were implanted into 400 Chilko Lake sockeye salmon smolts at the DFO counting fence as they began their outmigration to the Pacific Ocean. This site is situated 750 km inland from the ocean and is the highest elevation rearing lake for sockeye salmon in Canada. Fish were surgically implanted with V7 transmitters, in an identical fashion to 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. We also tagged ~ 20 adult bull trout with V13 transmitters in order to more closely examine predator-prey relationships. Our recent work has shown that bull trout may account for large levels of smolt mortality during early departure from the natal lake. We are using a VPS positioning system involving ~20 receivers, in partnership with VEMCO, to assess. The Chilcotin receivers have been retrieved and downloaded. But the VPS receivers are still in position and will be retrieved next spring. The lower Fraser array will be downloaded by Kintama in November 2014. The marine arrays will be 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 2014.

We are taking two approaches to examine this multi-year dataset 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. 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 shortly 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.

d) Coordination and integration

Several face-to-face meetings, conference calls, Skype and email virtual meetings were held over the past year for purposes of integration, planning, logistics, and coordination within Pacific Arena projects.

Adult Salmon studies (Projects 4.12 and 4.13)

October 2013 (to September 2014) – numerous communications between Martins and Joanna Mills-Flemming (Dalhousie) related to spatial analyses of fish telemetry data.

October (to December) 2013 – Donaldson (PDF) actively mentored Amy Teffer (PhD) and Art Bass (PhD) on experimental design and data collection for laboratory-based holding experiments and field-based telemetry studies.

October 2013 (to July 2014) – bi-weekly meetings at UBC to discuss tagging study results, monthly and annual reports, and planning for upcoming field work (Hinch, Burnett, Casselman, Bett, Middleton, Braun, Minke-Martin, White)

October 2013 (to September 2014) – Martins actively mentored Drenner (PhD), Furey (PhD), Middleton (MSc) and Minke-Martin (MSc) on study design and data analysis.

November 18, 2013 – meeting at UBC between Bett and Dr. Sang-Seon Yun to discuss research progress with tagging studies and olfaction

December 5, 2013 – meeting at UBC to discuss tagging projects in the Seton watershed (Nolan Bett, Doug Braun, Nich Burnett, Matt Casselman, Scott Hinch, Eduardo Martins, Collin Middleton)

December 12, 2013 – Martins and Casselman met to discuss data analysis and database development for Seton River tagging study.

January 5, 2014 – meeting at the DFO Pacific Biological Station with Kristi Miller and Amy Teffer to discuss laboratory approach for analysis of Chinook salmon tissue samples collected in summer 2013.

January 14, 2014 – meeting at UBC with Dr. Patricia Schulte to discuss the analysis of real time PCR data

January 15, 2014 – Drenner (PhD) meeting with Kristi Miller (DFO collaborator, OTN PI) at DFO Pacific Biological Station in Nanaimo to discuss and analyze genomic data related to 2010 sockeye salmon tagging project.

January 17, 2014 – meeting at UBC (Minke-Martin, Hinch and Donaldson) to discuss investigator handling and tagging literature and opportunities for a review paper targeted to managers

January (to September) 2014 – Drenner had several email/Skype communications with Richard Thomson (DFO collaborator, OTN PI) in regards to oceanography data integration and interpretation of 2010 sockeye salmon telemetry study. This study has now been submitted for publication to Fisheries Oceanography.

February 6, 2014 – meeting (Cooke, Donaldson, Minke-Martin) at UBC to discuss investigator handling and tagging literature and opportunities for a review paper targeted to managers

February 6, 2014 – Drenner (PhD) met with collaborators Kristi Miller (DFO-PBS, OTN PI), Tony Farrell (OTN PI), David Patterson (DFO collaborator), and Eduardo Martins (RA) to discuss progress of sockeye salmon telemetry project.

February 20, 2014 –meeting at UBC (Hinch, Casselman, Burnett, Middleton, Bett) to discuss tagging results and plan upcoming field season

February 26, 2014 – meeting at UBC between Bett and Dr. John Taylor to discuss the analysis of real time PCR data and the expression of olfactory-related genes in fish

February (to September) 2014 – E. Eliason, D. Patterson, K. Robinson, M. Dick, and S. Cooke had several meetings (conference call; Skype) to discuss tagging effects.

February (to July) 2014 – E. Eliason, S. Hinch and S. Healy met several times at UBC to discuss the sex-bias in en route mortality for Pacific salmon.

February (to July), 2014 – monthly meetings (face-to-face and Skype) between Cooke, Hinch, Martins and Donaldson to develop thought piece on telemetry in the context of current survivorship estimation methods used by managers of Pacific salmon.

March 5, 2014 – Cook met with Colin Brauner (Zoology department, UBC) to discuss experimental design and best methodologies for assessing recovery in salmon

March 5, 2014 – Cook met with Martins to overview the statistical methods of determining migration rates of coho salmon released with acoustic tags

March 20, 2014 –meeting at UBC (Doug Braun, Burnett, Middleton) to plan analysis of temperature time-series data

March (to October) 2014 – Teffer actively provided advice for experimental design and planning to Vanessa Minke-Martin (MSc) and Jacqueline Chapman (PhD) regarding the use of molecular techniques to identify changes in infectious disease state and immunological responses of fish to stress and infection.

April 8, 2014 – meeting to discuss progress of projects (Drenner, Hinch, Miller, Farrell, Thomson)

April 9, 2014 - meeting at UBC between Bett and Dr. Sang-Seon Yun to discuss research progress with tagging studies and olfaction

April 14, 2014 – meeting at UBC to discuss upcoming ADCP work (Burnett, Casselman)

April 15, 2014 – conference call meeting to discuss tagging projects (Hinch, Patterson, Cooke, Dick, Chapman)

April 22, 2014 – Martins (RA) met with Nicholas Burnett (MSc) to discuss data analysis and visualization.

April 29, 2914 – Cook gave a presentation to HQP in Hinch lab entitled, "Factors influencing delayed mortality in Pacific salmon released from marine commercial fisheries: Research questions and thesis ideas" to receive feedback and ideas regarding proposed research

April (to July) 2014 - Eliason and Banet met several times to discuss experimental design and data collection. Eliason provided guidance on collecting respirometry data from Banet's control and cortisol exposed juvenile salmon.

April (to July) 2014 – monthly meetings between Minke-Martin and Eduardo Martins (PDF) for mentoring in telemetry and thermal time-series data analysis.

May 15, 2014 – meeting to discuss planning of activities for 2014 (Hinch, Casselman, Martins, Middleton, Burnett, Minke-Martin)

May 16, 2014 – conference call (Chapman, Dick, Cooke, Patterson) to discuss logistics of upcoming field season

May 27, 2014 – meeting at UBC to discuss research goals and student progress (Hinch, Teffer, Miller)

May 28, 2014 – meeting at UBC to discuss the potential for the use of a standardized injury monitoring protocol for fish that might predict survival (Bass, Casselman, Cook, Minke-Martin, Teffer).

May (to July) 2014 - monthly meetings at UBC to discuss field logistics and research goals for the 2014 Seton River tagging study (Hinch, Casselman, Burnett, Bett, Middleton, Minke-Martin)

June 3, 2014 – meeting in Ottawa (in conjunction with 4th OTN Symposium) to discuss potential social science project of successful and unsuccessful of telemetry findings integration into management – Arctic, Florida and British Columbia case studies (Kessel, Cooke, Nguyen)

June 11, 2014 – conference call to discuss Harrison River tagging (Eliason, Patterson, Cooke, Dick)

June 16, 2014 – meeting (Hinch and several HQP) to discuss timing and logistics of upcoming fieldwork at West Vancouver DFO laboratories, UBC, Cultus Lake DFO Laboratories and on the Fraser River.

June 20, 2014 – meeting to discuss progress of projects (Raby, Hinch, Cooke)

June 24, 2014 – meeting to discuss thesis progress and direction (Teffer, Hinch, Miller)

June 30, 2014 – meeting (Skype: Hinch, Teffer, Miller, Minke-Martin) to design pilot project analyzing pathogen loads in Gates Creek sockeye, to occur in conjunction with tagging study

July 3, 2014 - meeting to develop a standardized injury monitoring protocol for fish tagged in various locations in the Fraser River (Bass, Burnet, Casselman, Cook, Minke-Martin, Teffer).

July 9, 2014 – meeting to discuss potential fishing locations for tagging during fall of 2014 and receiver deployments (Bass, Cook, Lotto, Teffer, Burnett, Furey, Hinch)

July 10, 2014 – meeting at UBC (Braun, Burnett, Minke-Martin, Middleton) to plan sampling and analysis for reproductive assessments of adult female Gates Creek sockeye on spawning grounds

July 10-14, 2014 – several meetings at the University of Victoria, B.C. developing a theoretical framework and statistical strategy for analysis of longitudinal infectious disease data (holding studies) with in-river telemetry tracking data (Teffer, Bass, Miller)

July 14, 2014 – meeting at the Pacific Biological Station, Nanaimo, B.C. to discuss progress in molecular analyses (Teffer, Miller).

July 15, 2014 – field season planning meeting at UBC (Hinch, Teffer, Cook, Eliason, Bass)

July 9, 2014 – meeting (Middleton, Hinch, E. Martins, and Dr. Kathy Martins – UBC Forestry) to discuss Middleton research progress to date, evolution of thesis direction and guidance for 2014 field season planning.

July 21, 2014 - meeting at SFU to discuss sample sizes for the tagging projects (Martins, Eliason, Patterson, Robinson, Dick).

July (to October) 2014– Eliason (PDF) actively mentored Melissa Dick (MSc candidate) on experimental design, data analysis and fish physiology.

August 15, 2014 – Skype meeting to discuss fish physiology component of tagging project (Eliason, Dick, Cooke)

August 20, 2014 – Chapman meeting with Kristi Miller to discuss and schedule gene and pathogen expression work for upcoming field season

August 23, 2014 – Cooke, Miller and Chapman met at Quebec City AFS conference to discuss incorporation of genomic tools into Chapman's thesis.

August 26, 2014 - Eliason advised Cook on experimental design and exercise physiology in fish sampling methods for a short-term holding study to be conducted at UBC assessing recovery from capture stress in both marine and freshwater environments

August 27, 2014 – meeting at UBC to discuss progress and field plans for 2014. Attending by phone: Hinch, Cooke, Farrell, and Miller.

September 4-5, 2014 – meeting in Lilooet, BC to discuss the tagging and to install receiver stations on the Birkenhead River (Patterson, Robinson, Dick, Casselman, Minke-Martin, Middleton)

September 9, 2014 – Meeting at UBC to discuss capture and transportation of fish from the Center for Aquaculture & Environmental Research in West Vancouver to the Cultus Lake Salmon Research Laboratory (15 HQP participants)

September 10, 2014 - meeting at UBC between Bett and Dr. Sang-Seon Yun (UBC Zoology Dept.) to discuss olfaction in salmon homing.

September 2014 – Drenner mentored Cook and Bass on fish tracking/tagging techniques.

September (to October) – several fact to face meetings between Chapman, Teffer, Bass, Dick on experimental design, sampling techniques and field logistics involving coho salmon tracking study.

Sturgeon study (Project 4.14)

March 26, 2014 – research planning meeting to discuss tag programming options for upcoming White sturgeon project (McLean, Crossin, Cooke)

April 7, 2014 – research planning meeting for upcoming White sturgeon tagging project field season 1 held at Dalhousie University, Halifax, Nova Scotia (McLean, Crossin, Litvak, Whoriskey, Iverson)

May 1, 2014 – research planning meeting with the Ministry of Environment of British Columbia on obtaining permits and collaborative tracking efforts for the White sturgeon tagging project (McLean)

May 5, 2014 – research planning meeting before commencing field season 1 of the White sturgeon tagging project in British Columbia (McLean, Litvak)

June 7, 2014 – research progress meeting at the Annual OTN Canada Symposium, Ottawa, Ontario (McLean, Crossin, Whoriskey)

June 11, 2014 – meeting in Halifax (in conjunction with Coastal Zone Canada Conference) to discuss potential social science studies with sturgeon recreational fisheries (Pacific) in the Fraser River (Crossin and Nguyen)

June 18, 2014 – research planning meeting with collaborators at the Abernathy US Fish and Wildlife Fish and Tech. Center in Longview, WA about upcoming stress studies on captive white sturgeon to validate field techniques (McLean, Kyle Hanson (US Fish and Wildlife))

Smolt and Juvenile Salmon studies (Project 4.15)

December 2013 to January 2014 - Nathan Furey and Dr. Mike Foreman (DFO) transfer ocean simulation model files to UBC for continued development of individual-based model (IBM) of salmon smolt migrations in the Salish Sea.

January 20, 2014 - Skype meeting to discuss data analysis for Chilko Lake sockeye salmon smolt project (Jeffries, Welch, Rechisky, Porter).

January 31, 2014 – meeting at UBC to discuss research (Furey, Hinch, David Welch, Evgeny Pakhomov, Sarah Gergel)

February 5, 2014 - Sopinka, Hinch, Cooke and Patterson met to discuss write-up of data for peer-reviewed publication and Natalie's PhD thesis.

August 14, 2014 – Furey (HQP) and Martins (RA) meet to plan analyses of acoustic telemetry data collected on sockeye salmon smolts and bull trout at Chilko Lake, BC, and discuss potential new avenues of research.

e) Scientific and/or engineering significance

1) 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 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. The fact that > 2/3rd of First Nations fishers trusted the results of telemetry science and felt positively about how it could help fisheries management and that a majority felt that recovery bags were a good idea to implement means that we have been able to get 'buy-in' from academic science by one of the most influential and fastest growing fisheries sectors.

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 failure. 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 conducted the first ever telemetry studies examining delayed mortality in adult salmon released from estuarine and ocean gillnet fisheries. This year we published 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) 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.

5) 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 regulation on angling activity. A typical angling event can last upwards of 1 hour, which is an enormous stress. Our preliminary results with RAMP assessment are showing direct relationships with physiological indicators of stress (plasma lactate and glucose levels), which will enable fishers and managers to use RAMP to assess the condition of fish prior to release. Our future work, both with wild caught fish and fish in captivity, will enable us to refine these RAMP-physiology relationships. And field tests, where RAMP assessed fish are then monitored via acoustic telemetry, will enable us to link RAMP to post-release behaviour and survival.

7. Difficulties encountered

☒ Equipment and technology issues (e.g. delivery and malfunctioning of equipment)

Equipment missing (project 4.14) - The sturgeon project borrowed 15 VR2 receivers from the OTN in 2014 to expand the lower Fraser River acoustic array and increase our chances of detecting tagged sturgeon. However, of the 15 VR2 receivers deployed, 10 are missing. There was no budget in the CFI to deploy these so OTN agreed to cover the costs of deployment as we were in effect expanding the OTN Pacific Arena array. OTN recommended that we should use Mike Boyd, a commercial diver that OTN uses frequently to deploy receivers in the marine areas. Many of the receivers were going into the Harrison and Pitt Rivers, locales where Pacific Arena researchers have considerable experience in prior deployments and recovery of receivers. Unfortunately all knowledgeable HQP and technicians were unavailable to go to the field with the diver on the days he was available. We gave clear instructions to the diver as to where specifically, and how specifically, receivers should be placed in these areas. In our experience log booms and their pilings are the safest as they resist flow changes, will prevent entanglement in fishing gear, and enable easy access for download. Unfortunately the diver chose to not use these structures and instead place the receivers using anchors and chains, and other sorts of ballast (which may work in marine areas, but not riverine areas). The BC Wildlife Federation has posted information on their website on this issue of 'lost gear' including the OTN phone number and reward for recovery.

VMT deployments (project 4.14) - Vemco Mobile Receivers (VMTs) were purchased this past year for deployments on sturgeon. VMTs are a combined acoustic receiver and transmitter which can be fitted directly onto the fish's backs, these 'bio-probes' are able to detect other tagged animals as they freely move throughout the river system. Our goal was to deploy these in summer 2014 but we were unable to develop and test a safe and reliable method of attachment. These tests will take place in 2015 and we hope deployments to begin after that.

8. Networking and outreach

a) Intra-network collaboration and partner meetings

October 2013 (to September 2014) – Numerous communications between Martins and Joanna Mills-Flemming (Dalhousie) related to spatial analyses of fish telemetry data.

November 7, 2013 – Banet met with Environmental Watch Team (DFO collaborators) to discuss fertilization success of Stellako sockeye eggs fertilized in home stream vs. UBC water.

November 19, 2013 – Banet met D'Arcy McKay (DFO Collaborator) to coordinate data collection efforts on incubating gametes.

December 17, 2013 – PI's (Cooke, Hinch, Young) and UBC students (Bass, Cook, Teffer) met with representatives from DFO (Patterson, Payne, Teffer) to discuss research priorities for DFO and the origin of mortality estimates currently being used to manage fisheries in coastal BC.

December 17, 2013 – Cook met with Young to discuss potential for introducing social science work into thesis research understanding bycatch mortality and bycatch handling protocols in costal fisheries of BC

February 5, 2014 – Meeting (Middleton, Cooke, Patterson - DFO collaborator) to discuss results from 2013 field season examining the role of changing olfactory landscapes on migrating adult Pacific salmon in a regulated watershed.

February 6, 2014 – Pacific Arena hosts its annual full day research update workshop at UBC involving presentations by several HQP to an audience of ~60 attendees including collaborators, stakeholders, fishing groups, ENGOs, and government scientists/managers.

February 7, 2014 – McLean, Crossin, Cooke and Hinch hosted a workshop at UBC to discuss the upcoming White sturgeon tagging project. 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), Matt Litvak (OTN PI for Atlantic arena and co-supervisor on my project), Steve McAdam (BC Ministry of Environment), Dan Baker (Post-doc at the International Centre for Sturgeon Studies at Victoria Island University), Kyle Hanson (physiologist from the U.S. Fish and Wildlife Abernathy Fish Technology Center, Washington, USA), and Lee Williston (Fisheries Biologist with BC Fish and Wildlife working on White sturgeon in the upper Fraser River).

February (to July) 2014 – Eliason met several times at SFU to discuss the development of a model (with DFO collaborators) to simulate en-route mortality for Fraser River sockeye salmon based on population-specific thermal tolerance.

March 11, 2014 - Banet met with the Environmental Watch Team (DFO collaborators) to discuss incubation progress from Harrison and Weaver sockeye eggs.

March 13 (26 and May 28), 2014 – Raby and Chapman participated in teleconference planning meetings (Kyle McKenzie, Nikki Beauchamp, and Tracy Rounds at Dalhousie) to help organize the 4th annual OTN Canada symposium (held in Ottawa June 3-4).

April 4, 2014 - Banet had a phone meeting with the Environmental Watch Team (DFO collaborators) to discuss incubation data from Harrison and Weaver sockeye.

April 12 (to May 5), 2014 – Raby traveled to Australia to work with OTN collaborator Dr. Tim Clark (Australia Institute of Marine Science) on data analysis, processing, and writing of OTN projects conducted in 2011.

April (to October) 2014 - Kessel (Arctic Arena, PDF) proposed a collaborative paper with Nguyen (Pacific Arena, PhD), Cooke (Pacific Arena), Nigel Hussey (Arctic Arena), Aaron Fisk (Arctic Arena) and Kyle Kenneth McKenzie (OTN).

May 6, 2014 – Marianne Corriveau (MA) met with Heather James (DFO) seeking advice on evaluating impact of telemetry knowledge and research on DFO policy and decision-making.

May 21, 2014 – Raby traveled to the University of Windsor to discuss a potential post-doctoral fellowship role there, working under the mentorship of Dr. Aaron Fisk (OTN Canada Arctic Arena leader).

June 4, 2014 – Meeting in Ottawa (during 4th OTN Canada Symposium) to discuss potential application in the Atlantic arena of a fish reflex assessment method developed and validated in the Pacific arena (Raby, Cooke, E. Halfyard)

June 6, 2014 – Nathan Young (U Ottawa) participated in OTN knowledge mobilization workshop in Ottawa, with representatives of DFO and industry.

June 6, 2014 – following the OTN meeting, Miller forged a collaboration with Ian Fleming in order to conduct genomic analysis of his kelt samples.

June 16, 2014 – meeting at SFU (Patterson, DFO collaborator; Eliason; Minke-Martin) to discuss modeling of adult sockeye salmon thermal behaviour in natal lakes using data collected from Gates Creek sockeye thermal loggers in 2013.

June (to October) 2014 - proposed collaboration between Nathan Young and Nguyen (U Ottawa) with Mclean and Crossin on including social science component to her PhD project with sturgeon in the Pacific.

July 4, 2014 – Martins participated in a Skype call with Sara Iverson, Cooke and Michael Power to discuss telemetry projects in the Amazon and the potential expansion of OTN activities in that system.

July 28-30, 2014- Furey attended OTN-sponsored workshop at Dalhousie University (organized by Joanna Mills-Fleming and Ian Jonsen) to learn modelling and visualization techniques. During this workshop Furey also held separate meetings with Mills-Fleming and Jonsen to discuss future collaborations to analyse fine-scale movement data of sockeye salmon smolts and bull trout.

September 9, 2014 – Martins participated in a teleconference with Sara Iverson, Fred Whoriskey, Cooke, Michael Power and several Brazilian researchers to discuss the realization of a workshop on telemetry work being conducted in Brazil and the plans for expansion of OTN activities in the country. The workshop is planned for February 2015 during the annual conference organized by the Brazilian Society of Ichthyologists.

September 16, 2014 - Cooke and Aaron Fisk met to discuss Arctic component of the catch-and-release study being conducted in three Oceans. Cooke provided the Arctic Arena team with field physiology sensor tools for measuring blood physiology of Arctic animals and then provided input on analysis.

September 2014 – Jeff Beardsall (MSc – Atlantic arena) brought his knowledge of external tagging methods from the Atlantic arena to aid in the development of an external tag unit for white sturgeon in the Pacific arena white sturgeon tagging project.

October 19, 2014 – Banet and Sopinka met with DFO collaborators Jayme Hills and Taylor Nettles to coordinate hormone assays of egg and plasma data at the DFO West Vancouver Lab.

October 23, 2014 - Banet worked with the Environmental Watch Team (DFO collaborators) to collect biopsy data and gametes from Weaver sockeye.

October 2013 (to October 2014) – monthly meetings (Hinch, Burnett, Casselman) with University of Alberta hydrodynamic lab (Dr. David Zhu and colleagues) to discuss linkages between fish tracking and ADCP research.

March (to August) 2014 - numerous discussions between Lotto and Keri Benner (DFO stock assessment senior biologist) about OTN projects that are occurring in the Fraser Watershed and coordination needed by DFO for run timing data, permitting, and communication to stakeholder groups.

May 21, 2014 – Lotto met with Kim Charlie (Fisheries Coordinator, Chehalis First Nation) to discuss upcoming research projects in their territory and arranging to hire their fisheries crews.

August 13, 2014 – meeting (Middleton, Patterson – DFO collaborator) discuss experimental design / data analyses of recent telemetry results.

b) Interaction/Outreach to Broader Community

October 8, 2013 – McLean was a guest lecturer for the Transatlantic Research School for Ocean System Science and Technology (TOSST) Dalhousie University, NS, where she discussed her role within the OTN, gave an introduction to fish tracking and telemetry, and presented her 2010-2012 telemetry data.

November 6, 2013 – Middleton, Casselman, Bett and Burnett presented summaries of research results at BC Hydro and St'at'imc EcoResources community meeting in Lillooet, BC.

November 19, 2013 – Presentation by Sopinka to the Pacific Salmon Commission on Maternal and environmental influences on juvenile life history and population dynamics of sockeye salmon.

November 25, 2013 – Cook met with Greg Taylor (Fish First Consulting, Vancouver, BC) to overview chum bycatch issues in Area 6 and the potential for new research on the Skeena River in BC.

December 18, 2013 – Martins participated in a conference call to update the MCA-REV Fish Entrainment Technical Committee on the final findings of the research done in collaboration with Steven Cooke, Michael Power, Joann Mills-Flemming and Ian Jonsen.

January 10, 2014 – Banet gave a tour of the UBC Pacific Salmon Wet Lab to BC Assistant Deputy Ministers of Education Bobbi Plecas (Institutions and Programs Division) and Claire Avison (Sector Strategy and Quality Assurance Division).

January 8, 2014 – McLean gave a presentation to a 3rd grade class at an elementary school in Manhattan, New York about the Ocean Tracking Network and using telemetry to understand the behaviour of aquatic animals.

January 24, 2014 – McLean was a guest lecturer in the Biology Department of Dalhousie University, NS, where she discussed the OTN, presented her 2010-2012 telemetry data and discussed her upcoming White sturgeon tracking project commencing in the summer of 2014.

February 21, 2014 – Lotto, Bass, Teffer meeting with the Lower Fraser Fisheries Alliance at the Sumas First Nations Band Office (Sardis, BC) to present research results from 2013, discuss future research directions, and enlist community support to assist with fishing efforts.

March 5, 2014 – McLean was invited to present her upcoming White sturgeon tagging project research objectives to the Community Working Group – a group that was formed as part of the COSEWIC recovery strategy for White sturgeon. Many government and non-government stakeholders were present at the meeting that was held in BC. McLean was in NS and phoned in to participate.

March 6, 2014 – Lotto, Furey, Bass attended the TSILHQOT'IN National Government Fisheries Forum in Williams Lake BC to present research results from 2013 and discuss future research directions in their territory.

March 8, 2014 - Lotto phone meeting with Mike Ramsey (senior provincial fisheries biologist, Williams Lake BC) to review upcoming bull trout tagging research and UBC discussions with the TSILHQOT'IN First Nations.

March 13, 2014 – McLean gave a presentation to a 4th year undergraduate journal club at Dalhousie University about the Ocean Tracking Network and her 2010-2012 telemetry research.

March 2014 - Natalie Sopinka led the fundraising efforts for the silent auction held at the 2014 American Fisheries Society (AFS) Washington-British Columbia Chapter Annual General Meeting in Vancouver, Washington. OTN was a prize donor and all proceeds fund student scholarships and research. Natalie gave a talk on science communication at the meeting and co-won best student oral presentation.

March 24-28, 2014 – Martins traveled to Brazil to teach in a 5-day course on the application of telemetry techniques to fisheries research. Examples of research conducted under OTN Pacific Arena and HydroNet were presented. The course was organized by Neotropical Consulting and Lotek Wireless Inc.

April 15, 2014 – Cook presented results from coho salmon bycatch research to CANFISCO, the Canadian fishing company head corporate office in Vancouver, BC. A question period and a discussion regarding how these results may apply to other fishing zones in the central coast followed. Representatives from Watershed Watch Salmon Society, the David Suzuki Foundation, and Fishfirst Consulting were also present.

April 26, 2014 - Sopinka spoke to the Macoun Field Club of the Ottawa Field-Naturalists' Club in Ottawa. She talked with the youth members about Pacific salmon life history and how the lab uses telemetry to study salmon.

April 28 (to May 2), 2014 – Martins attended the 4th HydroNet Symposium, where he presented the findings of his research done with Steven Cooke, Michael Power, Joann Mills-Flemming and Ian Jonsen.

May 6, 2014 – Erika Eliason gave a presentation to the Pacific Salmon Commission - Local adaptation and thermal tolerance among Fraser River sockeye salmon populations. M. Lapointe, S. Latham and E. Eliason discussed integrating population-specific thermal tolerance into management plans, which populations still need further research, and whether ocean and spawning ground sex ratio data could be shared among researchers.

May 22, 2014 – Banet participated in a UBC high school outreach program where she presented and led activities on how animal locomotion is researched by scientists, including information about that Hinch lab research that focuses on salmon swimming performance.

May 23, 2014 – Banet gave a presentation to the dean of UBC's Faculty of Forestry and 17 other members of the faculty. The presentation highlighted research projects in the Hinch Lab and was followed by a tour of the UBC Pacific Salmon Wet Lab.

May 24, 2014 – Banet gave a presentation to the UBC Faculty of Forestry class of 1968 as part of UBC's alumni weekend. The presentation highlighted research projects in the Hinch Lab and was followed by a tour of the UBC Pacific Salmon Wet Lab.

May 24, 2014 – Banet gave a presentation to prospective undergraduates in the UBC Faculty of Forestry. The presentation highlighted research projects in the Hinch Lab and was followed by a tour of the UBC Pacific Salmon Wet Lab.

May 24, 2014 - Nguyen (PhD), Sopinka (PhD), Chapman (MSc), Ward (UG) and other students from the Fish Ecology and Conservation Physiology lab (Carleton University) hosted World Fish Migration Day event in Ottawa that included activities and showcases at the Nature Museum followed by a pub talk by Dr. David Browne (Canadian Wildlife Federation) and Dr. Nick Lapointe (Nature Conservancy Canada).

May 18, 2014 – Bass presentation to the Lower Fraser Fisheries Alliance, a consortium of First Nations fishers, on research from 2013.

May 29, 2014 - Meeting with the Lower Fraser Fisheries Alliance Science Forum (Chilliwack, BC); At this meeting several of our research group HQP presented overviews of recent research results and proposed research for coming field season in order to seek First Nations assistance with capturing fish. We made numerous contacts for fishing assistance at this meeting.

June (to September) 2014 – Lotto had several phone and in person meetings with numerous First Nations fishing groups and individuals to negotiate costs and timing to hire fishers, and plan fishing activities in First Nations territories (including Mike Baird, Twassen First Nations; Les Antone, Ashley Doyle and Drew Adkins, Kwantlen First Nations; Kim Charlie, Chehalis First Nations; Chief Norma Webb Peters Band).

June 18 (and 24), 2014 - Casselman presented an overview of results from the 2013 Seton River acoustic telemetry studies to Chiefs and elders of the N"Quatqua First Nations (D'Arcy, BC) and the Tsal'alh First Nations (Shalath, BC).

August 12, 2014 – Site visit to a gillnet vessel in Steveston BC belonging to Mike Baird of the Tsawwassen First Nation and determine feasibility of conducting tagging experiments in the mouth of the Fraser River (Bass, Cook, Lotto)

September 2014 - Interacted and collaborated with commercial fishers Paul Brajchich and David Patterson (DFO collaborator) during coho marine tagging project.

9. Dissemination of information and results

a) Refereed journal articles (39 total) – accepted/published

Antilla, K., Eliason, E. J., Kaukinen, K. H., Miller, K. M., Farrell, A. P. (2014) Facing warm temperatures during migration - cardiac mRNA responses of two adult sockeye salmon Oncorhynchus nerka populations to warming and swimming challenges. Journal of Fish Biology, 84: 1439-1456.

Burnett, N. J., Hinch, S. G., Braun, D. C., Casselman, M. T., Middleton, C. T., Wilson, S. M., and Cooke, S. J. (In Press) Burst swimming in areas of high flow: delayed consequences of anaerobiosis in wild adult sockeye salmon. Physiological and Biochemical Zoology, 87(5): 587-598.

Burnett, N. J., Hinch, S. G., Donaldson, M. R., Furey, N. B., Patterson, D. A., Roscoe, D. W., and Cooke, S. J. (2014) Alterations to dam-spill discharge influence sex-specific activity, behaviour and passage success of migrating adult sockeye salmon. Ecohydrology, 7: 1094-1104.

Chen, Z., Antilla, K., Whitney, C. K., Hinch, S. G., and Farrell, A. P. (2013) Optimum and maximum temperatures of sockeye salmon (Oncorhynchus nerka) populations hatched at different temperatures. Canadian Journal of Zoology, 91: 265-274.

Cook, K. V., Crossin, G. T., Patterson, D. A., Hinch, S. G., Gilmour, K. M., and Cooke, S. J. (2014) The stress response predicts migration failure but not migration rate in a semelparous fish. General and Comparative Endocrinology, 202: 44-49.

Cooke, S. J., Killen, S. S., Metcalfe, J. D., McKenzie, D. J., Mouillot, D., Jørgensen, C., and Peck, M. A. (2014) Conservation physiology across scales: Insights from the marine realm. Conservation Physiology. DOI:10.1093/conphys/cou024.

Cooke, S. J., Nguyen, V., Murchie, K. J., Thiem, J. D., Donaldson, M. R., Hinch, S. G., Brown, R. S., and Fisk, A. (2013) To Tag or Not To Tag: Animal Welfare, Conservation and Stakeholder Considerations In Fish Tracking Studies That Use Electronic Tags. Journal of International Wildlife Law & Policy, 16(4): 352-374.

Cooke, S. J., Donaldson, M. R., O'Connor, C. M., Raby, G. D., Arlinghaus, R., Danylchuk, A. J., Hanson, K. C., Hinch, S. G., Clark, T. D., Patterson, D. A., and Suski, C. D. (2013) The physiological consequences of catch-and-release angling: perspectives on experimental design, interpretation, extrapolation, and relevance to stakeholders. Fisheries Management and Ecology, 20: 268–287.

Crossin, G. T., Cooke, S. J., Goldbogen, J. A., and Phillips, R. A. (2014) Tracking fitness in marine vertebrates: a review of current knowledge and opportunities for future research. Marine Ecology Progress Series 496: 1-17.

Donaldson, M. R., Hinch, S. G., Jeffries, K. M., Patterson, D. A., Cooke, S. J., Farrell, A. P., and Miller, K. M. (2014) Species- and sex-specific responses and recovery of wild, mature Pacific salmon to an exhaustive exercise and air-exposure stressor. Comparative Biochemistry and Physiology A, 173: 16-23.

Donaldson, M. R., Hinch, S. G., Suski, C. D., Fisk, A. T., Heupel, M. R., and Cooke, S. J. (In Press) Making connections in aquatic ecosystems with acoustic telemetry monitoring. Frontiers in Ecology and Environment. 00:000-000.

Drenner, S. M., Hinch, S. G., Martins, E. G., Robichaud, D., Thompson, L. A., Patterson, D. A., Cooke, S. J., and Thomson, R. E. (2014) Variable thermal experience and diel thermal patterns of homing sockeye salmon in coastal marine waters. Marine Ecology Progress Series, 496: 109-124.

Farrell, A. P., Eliason, E. J., Clark, T. D., and Steinhausen, M. F. (2014) Oxygen removal from water versus arterial oxygen delivery: calibrating the Fick equation in Pacific salmon. Journal of Comparative Physiology B (In press).

Furey, N. B., Hinch, S. G., Lotto, A. G., and Beauchamp, D. A. 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 (Accepted).

Gale, M. K., Hinch, S. G., Cooke, S. J., Donaldson, M. R., Eliason, E. J., Jeffries, K. M., Martins, E. G., and Patterson, D. A. (2014) Observable impairments predict mortality of captured and released sockeye salmon at various temperatures. Conservation Physiology, 2: 10.1093/conphys/cou029.

Hammerschlag, N., Cooke, S. J., Gallagher, A. J., and Godley, B. J. (In Press) Considering the fate of electronic tags: user responsibility and interactions with stakeholders and other scientists when encountering tagged aquatic animals. Methods in Ecology and Evolution. 00:000-000.

Harrison, P. M., Gutowsky, L. F. G., Martins, E. G., Patterson, D. A., Leake, A., Cooke, S. J., and Power, M. (2013) Diel vertical migration of adult burbot: a dynamic trade-off between feeding opportunity, predation avoidance, and bioenergetic gain. Canadian Journal of Fisheries and Aquatic Sciences, 70:1765-1774.

Jeffries, K. M., Hinch, S. G., Sierocinski, T., Pavlidis, P., and Miller, K. M. (2014) Transcriptomic responses to high water temperature in two species of Pacific salmon. Evolutionary Applications 7: 286-300.

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., and Miller, K. M. (Accepted pending minor revisions) Immune response genes and pathogen presence predict migration survival in wild salmon smolts. Molecular Ecology.

Jepsen, N., Aarestrup, K., and Cooke, S. J. (2014) Tagging fish in the field: ethical and procedural considerations. A comment on the recent paper of D. Mulcahy; Legal, ethical and procedural bases for the use of aseptic techniques to implant electronic devices. Journal of Fish and Wildlife Management 4, 211-219. Journal of Fish and Wildlife Management 5:000-000: doi: 10.3996/122013-JFWM-077.

Kessel, S. T., Cooke, S. J., Heupel, M. R., Hussey, N. E., Simpfendorfer, C. A., Vagle, S., and Fisk, A. T. (2014) A review of detection range testing in aquatic passive acoustic telemetry studies. Reviews in Fish Biology and Fisheries 24: 199-218.

Martins, E. G., Gutowsky, L. F. G., Harrison, P. M., Mills Flemming, J. E., Jonsen, I. D., Zhu, D. Z., Leake, A., Patterson, D. A., Power, M., and Cooke, S. J. (2014) Behavioral attributes of turbine entrainment risk for adult resident fish revealed by acoustic telemetry and state-space modeling. Journal of Animal Biotelemetry 2: 13.

Martins, E. G., Gutowsky, L. F. G., Harrison, P. M., Patterson, D. A., Power, M., Zhu, D., Leake, A., and Cooke, S. J. (2013) Forebay use and entrainment rates of resident adult fish in a large hydropower reservoir. Aquatic Biology, 19:253−263.

Miller, K. M., Teffer, A., Tucker, S., Li, S., Schulze, A. D., Trudel, M., Juanes, F., Tabata, A., Kaukinen, K. H., Ginther, N. G., Ming, T. J., Cooke, S. J., Hipfner, M., Patterson, D. A., and Hinch, S.G. (2014) Infectious disease, shifting climates and opportunistic predators: cumulative factors potentially impacting wild salmon declines. Evolutionary Applications, 7: 812-855.

Miller, K., Teffer, A. K., Patterson, D., Tucker, S., Li, S., Schulze, A., Tabata, A., Kaukinen, K., Ginther, N., Juanes, F., Ming, T., Cooke, S., Hipfner, M., Trudel, M., and Hinch, S. (2014) Infectious disease, shifting climates and opportunistic predators: cumulative factors potentially impacting wild salmon declines. Evolutionary Applications, 7(7): 812-855.

Naumann, C., Robinson, J. Freshwater, C. Hertz, E. Stormer, D. Teffer, A.K and F. Juanes. 2014. [Review of the book Overfishing: What everyone needs to know. by Ray Hilborn with Ulrike Hilborn]. Fisheries, 39(5): 222-222.

Nguyen, V. M., Martins, E. G., Robichaud, D., Raby, G. D., Donaldson, M. R., Lotto, A. G., Willmore, W. G., Patterson, D. A., Farrell, A. P., Hinch, S. G., and Cooke, S. J. (2014) Disentangling the roles of air exposure, gillnet injury, and facilitated recovery on the post-capture and release mortality and behavior of adult migratory sockeye salmon (Oncorhynchus nerka) in freshwater. Physiological and Biochemical Zoology, 87: 125-135.

Raby, G. D., Donaldson, M. R., Nguyen, V. M., Taylor, M. K., Sopinka, N. M., Cook, K. V., Patterson, D. A., Robichaud, D., Hinch, S. G., Cooke, S. J. (2014) Bycatch mortality of endangered coho salmon: impacts, solutions, and aboriginal perspectives. Ecological Applications, 24: 1803-1819.

Raby, G. D., Hinch, S. G., Patterson, D. A., Hills, J. A., Thompson, L. A., and Cooke, S. J. Mechanisms to explain purse seine bycatch mortality of coho salmon. Ecological Applications (accepted).

Raby, G. D., Cooke, S. J., Cook, K. V., McConnachie, S. H., Donaldson, M. R., Hinch, S. G., Whitney, C. K., Drenner, S. M., Patterson, D. A., Clark, T. D., and Farrell, A. P. (2013) Resilience of

pink salmon and chum salmon to simulated capture stress incurred upon arrival at spawning grounds. Transactions of the American Fisheries Society, 142: 524-539.

Robinson, K. A., Hinch, S. G., Gale, M. K., Clark, T. D., Wilson, S. M., Donaldson, M. R., Farrell, A. P., Cooke, S. J., and Patterson, D. A. (2013) Effects of post-capture ventilation assistance and elevated water temperature on sockeye salmon in a simulated capture-and-release experiment. Conservation Physiology [online serial] 1(1). DOI: 10.1093/conphys/cot015.

Sopinka, N. M., Hinch, S. G., Middleton, C. T., Hills, J. A., and Patterson, D. A. (2014) Mother knows best, even when stressed? Effects of maternal exposure to a stressor on offspring performance at different life stages in a wild semelparous fish. Oecologia, 175: 493-500.

Sopinka, N. M., Hinch, S. G., Lotto, A. G., Whitney, C. K., and Patterson, D. A. (2013) Does among-population variation in burst swim performance of sockeye salmon fry reflect early life migrations? Journal of Fish Biology, 83: 1416–1424.

Welch, D. W., Porter, A. D., Rechisky, A. L., Challenger, W. C., and Hinch, S. G. (2013) Critical Periods in the Marine Life History of Pacific Salmon? North Pacific Anadromous Fish Commission Technical Report No. 9: 179-183.

Whitney, C., Hinch, S. G., and Patterson, D. A. (2014) Population origin and water temperature affect development timing in embryonic sockeye salmon. Transactions of the American Fisheries Society, 143: 1316-1329.

Wilson, S. M., Hinch, S. G., Drenner, S. M., Martins, E. G., Furey, N. B., Patterson, D. A., Welch, D. W., and Cooke, S. J. (2014) Coastal marine and in-river migration behaviour of adult sockeye salmon en route to spawning grounds. Marine Ecology Progress Series, 496: 71-84.

Wilson, S. M., Taylor, J. J., Mackie, T. A., Patterson, D. A., Cooke, S. J., and Willmore, W. G. (2014) Oxidative stress in Pacific salmon (Oncorhynchus spp.) during spawning migration. Physiological and Biochemical Zoology, 87: 346-352.

Wilson, S. M., Raby, G. D., Burnett, N. J., Hinch, S. G., and Cooke, S. J. (2014) Looking beyond the mortality of bycatch: sublethal effects of incidental capture on marine animals. Biological Conservation, 171:61-72.

Young, N., Gingras, I., Nguyen, V. M., Cooke, S. J., and Hinch, S. G. (2014) Mobilizing new science into management practice: the challenge of biotelemetry for fisheries management, a case study of Canada's Fraser River. Journal of International Wildlife Law & Policy, 16: 331-351.

b) Refereed journal articles (11 total) – submitted

Bett, N. N. and Hinch, S.G. (In review) Olfactory navigation in the spawning migrations of anadromous fish: A review and introduction of the Hierarchical Homing Hypothesis. Submitted to Biological Reviews.

Cook, K.V., Lennox, R. J., Hinch, S. G., and Cooke, S. J. (In review) Fish out of water: How much air is too much. Submitted to Fisheries Research on Sept. 7, 2014

Drenner, S. M., Hinch, S. G., Martins, E. G., Furey, N. B., Clark, T. D., Cooke, S. J., Patterson, D. A., Robichaud, D., Welch, D. W., Farrell, A. P., and Thomson, R. E. Environmental conditions and physiological state influence estuarine behaviour of homing sockeye salmon. Submitted to Fisheries Oceanography.

Eliason, E. J. and Farrell, A. P. (In review) Oxygen uptake in Pacific salmon: When ecology and physiology meet. Submitted to Journal of Fish Biology.

Gutowsky, L. F. G., Harrison, P. M., Martins, E. G., Leake, A., Patterson, D. A., Power, M., and Cooke, S. J. Spatial distribution, home range size, and horizontal movement of adfluvial bull trout in a large hydropower reservoir: implications for movement ecology and conservation. Submitted to Oecologia.

Harrison, P. M., Gutowsky, L. F. G., Martins, E. G., Patterson, D. A., Cooke, S. J., and Power, M. Personality-dependent spatial ecology: evidence for spatially and temporally consistent 'resident' and 'mobile' behavioural types in a benthic fish. Submitted to Canadian Journal of Fisheries and Aquatic Sciences.

Moore, J. W., Beakes, M. P., Nesbitt, H. K., Yeakel, J. D., Patterson, D. A, Thompson, L. A., Phillis, C., Braun, D. C., Favaro, C., Scott, D., Carr-Harris, C., and Atlas, W. Emergent stability in a large free-flowing watershed. Submitted to Ecology

Raby, G. D., Wilson, S. M., Patterson, D. A., Hinch, S. G., Clark, T. D., Farrell, A. P, and Cooke, S. J. (In review) A physiological comparison of three techniques for reviving sockeye salmon exposed to a severe capture stressor during upriver migration. Submitted to Journal of Comparative Physiology B.

Raby, G. D., Hinch, S. G., Patterson, D. A., Hills, J. A., Thompson, L. A., and Cooke, S. J. (In review) Mechanisms to explain purse seine bycatch mortality of coho salmon. Invited feature article for a special issue in Ecological Applications on the use of acoustic telemetry in fisheries management.

Sopinka, N. M., Hinch, S. G., Healy, S. J., Raby, G. D., and Patterson, D. A. (In review) Effects of experimentally elevated egg cortisol on the morphology and swimming performance of juvenile Pacific salmon. Submitted to Ecology of Freshwater Fish.

Thiem, J. D., Dawson, J. W., Gleiss, A. C., Martins, E. G., Haro, A., Castro-Santos, T., Danylchuk, A. J., Wilson, A. J., and Cooke, S. J. Accelerometer-derived activity correlates with volitional swimming speed in lake sturgeon Acipenser fulvescens. Submitted to Journal of Fish Biology.

c) Conference presentations (12 total) – invited

Cooke, S. J. (2014) Future Horizons of Tracking Science. Ocean Tracking Network Meeting, June 2014, Ottawa, Canada. Panel Member.

Cooke, S. J. (2014) Pacific Salmon Science to Inform Fisheries Management: Lessons from the Front Line. GLATOS-GLFC Workshop, March 2014, Ann Arbor, MI. Invited Presentation.

Cooke, S. J. (2014) Physiology, Behaviour & Conservation: Solving fish and turtle bycatch problems through mechanistic integrated research. R.E. Peters Conference, February 2014, Biological Sciences Department, University of Alberta (Keynote Speaker).

Cooke, S. J. (2014) Catch-and-release science. ICES Working Group on Methods for Assessing Discard Fate. Copenhagen, Denmark. Invited Presentation (delivered via Skype), February 2014.

Cooke, S. J. (2014) Linking biotelemetry research to fisheries management. American Association for the Advancement of Science. Invited Presentation in Ocean Tracking Network Session, February 2014.

Cooke, S. J. (2013) Considering scale in conservation physiology. COST Action Conservation Physiology Workshop, October 2013, Invited Presentation. Faro, Portugal.

Cook, K. V., Drenner, S. M., Raby, G. D., Hinch, S. G., and Cooke, S. J. (2014) Evaluating mortality and causes of mortality in coho salmon released from purse seine fisheries. Western Division American Fisheries Society Annual Meeting. Mazatlan, Mexico, April 7-11.

McLean, M. F., Litvak, M., Hinch, S., Cooke, S., and Crossin, G. (May 2014) Understanding the consequences of recreational angling stress on the biology and movement of white sturgeon in the Fraser River, BC. Invited to give an an oral presentation at the Lower Fraser Fisheries Alliance, Squiala First Nation, Chilliwack, British Columbia.

Miller, K. M., Hinch, S., Patterson, D., Trudel, M., Tucker, S., Teffer, A., and Riddell, B. (2014) High throughput genomics applied to identify cumulative impacts of environmental and biological stressors on salmon. Keynote at the 144th Annual American Fisheries Society Meeting, Quebec City, Quebec, August 2014.

Miller, K. M., Teffer, A., Tucker, S., Li, S., Tabata, A., Hinch, S. G., Patterson, D. A., Juanes, F., and Riddell, B. (2014) Infectious disease, shifting climates, and opportunistic predators: cumulative factors potentially impacting wild salmon declines. Seventh International American Fisheries Society Symposium on Aquatic Animal Health, Portland, Oregon, USA.

Nguyen, V. M, Young, N., and Cooke, S. J. (2014) From Science to Governance: Ocean Tracking Network Pacific Salmon Case Study, Coastal Zone Canada Conference, Halifax, June 15-18, 2014.

Raby, G. D., Hinch, S. G., Patterson, D. A., Hills, J. A., Thompson, L. A., and Cooke, S. J. (2014) Mechanisms to explain purse seine bycatch mortality of coho salmon: interactions between injury, reflex impairment, physiology. Annual General Meeting of the American Fisheries Society, Quebec City. August 19.

d) Conference presentations (38 total) – contributed

Bass, A. L., Teffer, A. K., Cooke, S. J., Farrell, A. P., Miller, K. M., Patterson, D. A., and Hinch, S. G. (2014) Chinook salmon migration following a fishery encounter. Ocean Tracking Network Annual Meeting. Ottawa, Ontario. June 2.

Bass, A. L., Teffer, A. K., Cooke, S. J., Farrell, A. P., Miller, K. M., Patterson, D. A., and Hinch, S. G. (2014) Chinook salmon migration following a fishery encounter. Evolutionary Ethology and Ecology of Fishes Bi-annual Conference. Corvallis, Oregon. June 23.

Bett, N. N. and Hinch, S. G. (2014) Homestream detection by pink and sockeye salmon in a regulated river system. International Conference on Engineering and Ecohydrology for Fish Passage, University of Wisconsin, Madison, USA. June 9-11, 2014.

Bett, N. N. and Hinch, S. G. (2014) Behavioral response of migrating sockeye and pink salmon to adult conspecifics. Conference on Ecological and Evolutionary Ethology of Fishes, Oregon State University, Corvallis, USA. June 22-25, 2014.

Braun, D. C, Reynolds, J. D., and Patterson, D.A. (2014) Using watershed characteristics to inform cost-effective stream temperature monitoring. River Temperature: a Physical, Biological and Climate Change Perspective. Moncton University, Moncton Canada. March 5-6th, 2014.

Burnett, N. J., Hinch, S. G., and Cooke, S. J. (2014) Burst swimming in areas of high flow: delayed consequences of anaerobiosis in wild adult sockeye salmon. International Conference on Engineering and Ecohydrology for Fish Passage, University of Wisconsin, Madison, USA. June 9-11, 2014.

Burnett, N. J., Hinch, S. G., and Cooke, S. J. (2014) Burst swimming in areas of high flow: delayed consequences of anaerobiosis in wild adult sockeye salmon. 4th Annual OTN Symposium, Ottawa, Canada. June 3-4, 2014.

Cook, K. V., Drenner, S. M., Raby, G. D., Hinch, S. G., and Cooke, S. J. (2014) Evaluating causes of mortality in coho salmon released from purse seine fisheries in the Juan de Fuca Strait. Ocean Tracking Network Annual Meeting. Ottawa, Ontario, June 2-5.

Dick, M. (2014) Understanding tagging effects to facilitate stakeholder adoption of studies using electronic tags: a case study with adult Pacific salmon. Ocean Tracking Network Canada Fourth Symposium, June 2014, Ottawa, ON.

Donaldson, M. R., Eliason, E., Jeffries, K. M., Poesch, M., Drake, A., Braun, D., Hasler, C. T., Nguyen, V., Raby, G. D., Lennox, R., Swanson, H., Favaro, B., Bower, S., and Cooke, S. J. (2014) Early career perspectives on the future of freshwater fisheries science, management, and policy in Canada. 144th Annual Meeting of the American Fisheries Society, Quebec City, Quebec. August 2014.

Drenner, S. M., Hinch, S. G., Martins, E. G., Furey, N. B., Clark, T. D., and Thomson, R. E. (2014) Environmental and physiological associations with homing sockeye salmon behaviour in the Strait of Georgia, BC. The 4th Ocean Tracking Network (OTN) Canada Symposium. Ottawa, ON, Canada. June 3, 2014.

Eom, J., Bett, N., Dider, W., Close, D. A. and Yun, S. S. (2014) Impaired olfactory sensitivity of coho salmon exposed to increased carbon dioxide tension (Poster presentation). Interactive Conference on Integrative Salmonid Biology. Vancouver, Canada. June 10-12, 2014.

Furey, N. B., Hinch, S. G., Lotto, A. G., Bass, A. L., Minke-Martin, V., Middleton, C. T., Casselman, M. T., Clark, T. D., Rechisky, E. L., Gale, M., Jeffries, K., Porter, A., and Welch, D. W. (2014) Behaviour and survival of outmigrant sockeye salmon smolts. Annual Ocean Tracking Network Canada (OTN) symposium. Ottawa, Ontario, Canada. June 3, 2014.

Hahn, L., Martins, E. G., Garrone-Neto, D., and da Câmara, L. F. (2014) Migratory movements of large catfish in the Xingu River (Amazon) revealed by combined acoustic and radio telemetry. American Fisheries Society 144th Annual Meeting, Quebec, QC. August 17-21, 2014.

Hahn, L., Martins, E. G., da Câmara, L. F., and Marçal, A. S. (2014) Fishway use and movements of giant migratory catfishes downstream of a large hydropower dam in the Brazilian Amazon. International Conference on Engineering and Ecohydrology for Fish Passage, Madison, WI, USA. June 9-11, 2014.

Harrison, P. M., Gutowsky, L. F. G., Martins, E. G., Patterson, D. A., Cooke, S. J., and Power, M. (2014) Consistent individual differences in burbot home range, dispersal, movement and site fidelity: Evidence for personality-dependent spatial ecology. International Congress on the Biology of Fishes, Edinburgh, Scotland. August 3-7, 2014.

Hinch, S. G., Eliason, E. J., Farrell, A. P., Cooke, S. J., and Patterson, D.A. (2014) Ten years of lab and telemetry studies on Canada's largest salmon river finds exceptionally high mortality of migrating female sockeye: are they running out of gas, stressed, sick, or do they die of broken hearts? International Conference on the Biology of Fish. Edinburgh Scotland. Aug 3-7, 2014.

Martins, E. G., Gutowsky, L. F. G., Harrison, P. M., Langford, M., Mills-Flemming, J. E., Jonsen, I. D., Leake, A., Patterson, D. A., Zhu, D. Z., Power, M., and Cooke, S. J. (2014) Modeling fine-scale fish movements in environments with dynamic water levels and complex flows. Symposium on Animal Movement and the Environment, Raleigh, NC, USA. May 5-7, 2014.

Martins, E. G., Gutowsky, L. F. G., Harrison, P. M., Langford, M., Mills-Flemming, J. E., Jonsen, I. D., Leake, A., Patterson, D. A., Zhu, D. Z., Power, M., and Cooke, S. J. (2014) Behavioural attributes of entrainment risk for adult bull trout in a hydropower reservoir. American Fisheries Society 144th Annual Meeting, Quebec, QC. August 17-21, 2014.

McLean, M. F., Litvak, M., Hinch, S., Cooke, S., and Crossin, G. (2014) Understanding the consequences of recreational angling stress on the biology and movement of white sturgeon in the Fraser River, BC. Abstract accepted for a poster presentation at the 5th International Bio-logging Science Symposium, September 2014, Strasbourg, France.

McLean, M. F., Litvak, M., Hinch, S., Cooke, S., and Crossin, G. (2014) Understanding the consequences of recreational angling stress on the biology and movement of white sturgeon in the Fraser River, BC. Accepted for a poster presentation at the 4th Annual Ocean Tracking Network Canada Symposium, June 2014, Ottawa, Ontario.

Middleton, C. T., Hinch, S. G., Martins, E. G., Burnett, N. J., Braun, D. C., and Casselman, M. (2014) Daily varying olfactory cues and their effects on Pacific salmon migration. Annual OTN Symposium, University of Ottawa. June 2, 2014.

Middleton, C. T., Hinch, S. G., Martins, E. G., Burnett, N. J., Braun, D. C., and Casselman, M. (2014) Daily varying olfactory cues and their effects on Pacific salmon migration in a regulated river. International Conference on Engineering & Ecohydrology for Fish Passage. University of Wisconsin, Madison. June 10, 2014.

Minke-Martin, V., Hinch, S. G., and Middleton, C. T. (2014) Thermal behaviour of adult sockeye salmon following a migration challenge. Evolutionary Ecology and Ethology of Fishes Conference. Oregon State University, Corvallis, USA. June 22-26, 2014.

McLean, M. F. (2014) Understanding the consequences of recreational angling stress on the biology and movement of white sturgeon in the Fraser River, BC. Abstract accepted for oral presentation at the 7th Annual Dr. Patrick Lett Symposium "Which Direction is Your Science Going?" March 2014, Dalhousie University, Halifax, Nova Scotia.

Nguyen, V. M., Corriveau, M., Cooke, S. J., Hinch, S. G., 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., Corriveau, M., Cooke, S. J., Hinch, S. G., and Young, N. (2014) Knowledge Mobilization: Moving Scientific Knowledge into Pacific Salmon Fisheries Management. American Fisheries Society 143rd Annual Meeting, Quebec City, Canada, Aug 17-21, 2014.

Nguyen, V. M, Young, N., and Cooke, S. J. (2014) Transcending the Disciplines. Ocean Tracking Network Symposium, Ottawa, CA, June 3-5, 2014.

Raby, G. D., Clark, T. D., Farrell, A. P., Patterson, D. A., Bett, N. N., Wilson, S. M., Willmore, W. G., Suski, C. D., Hinch, S. G., and Cooke, S. J. (2014) Facing the river gauntlet: understanding the effects of bycatch on the physiology of coho salmon. 4th annual OTN Canada symposium, Ottawa.

Rechisky, E. L., Welch, D. W., Porter, A. D., Gale, M. K., Clark, T. D., Furey, N. B., and Hinch, S. G. (2014) Telemetry-based estimates of survival and residence times of juvenile sockeye in the Strait of Georgia and Discovery Passage. Salmon Ocean Ecology Meeting. Santa Cruz, California, U.S.A. March 12-14, 2014.

Rechisky, E. L., Welch, D. W., Porter, A. D., Gale, M. K., Clark, T. D., Furey, N. B., and Hinch, S. G. (2014) Telemetry-based estimates of survival and residence times of juvenile sockeye in the Strait of Georgia and Discovery Passage. Oral Presentation at the CSAS State of the Pacific Ocean. Nanaimo, British Columbia. February 19, 2014.

Sopinka, N. M., Healy, S., Patterson, D. A., Jeffrey, J. D., Gilmour, K. M., and Hinch, S. G. (2014) Stress, huh yeah, what is it good for? Effects of maternal stress and egg glucocorticoids in Pacific salmon. Ecological and Evolutionary Ethology of Fishes, Oregon State University, Corvallis, USA. June 22-26, 2014.

Sopinka, N. M. (2014) From 3 lines to 3 minutes: sharing fisheries research in creative ways. Ocean Tracking Network Annual Meeting, Ottawa, Ontario, Canada. June 3-5, 2014.

Sopinka, N. M. (2014) From 3 lines to 3 minutes: sharing fisheries research in creative ways. American Fisheries Society Washington-British Columbia Chapter Annual General Meeting, Vancouver, Washington, USA. March 24-27, 2014. *Co-won Best Student Oral Presentation

Stokesbury, M. J. W., Beardsall, J. W., Logan-Chesney, L., and, McLean, M. F. (2014) Estimates of survival at varying temporal scales for fishes in the marine environment using electronic tagging technology. International Commission for the Exploration of the Sea, Annual Scientific Meeting, 15-19 September, La Caruna, Spain.

Stokesbury, M. J. W., Beardsall, J., McLean, M. F., and Dadswell, M. J. (2014) Tagging and genetics reveal the origin of Atlantic Sturgeon Acipenser oxyrinchus in Minas Basin, Nova Scotia: Potential effects of local impacts on a mixed stock aggregation. Accepted for an oral presentation at the 144th Annual American Fisheries Society Meeting, August 2014, Quebec City, Quebec.

Teffer, A. K., Miller, K., Patterson, D., Farrell, A., Jeffries, K., Cooke, S., Juanes, F., and Hinch, S. (2014) Stress and disease susceptibility of wild adult Pacific salmon. 11th International Congress on the Biology of Fish, Edinburgh, Scotland. August 3 – 7.

Teffer, A. K., Miller, K., Farrell, A., Cooke, S., Jeffries, K., Juanes, F., and Hinch, S. (2014) Stress and disease potential of wild adult coho salmon. American Fisheries Society, Western Division Annual Meeting. Mazatlán, Mexico. April 7 – 11.

10. Other contributions and deliverables

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

September 2014 – Furey was interviewed by the Pacific Salmon Foundation (PSF) regarding acoustic telemetry research on migrating sockeye salmon smolts. This project, and Furey's interview, will be highlighted in the PSF's upcoming annual newsletter.

September 23, 2014 - Erika Eliason was interviewed for a Japanese wildlife TV show entitled "WILDLIFE" for NHK, Japan's public broadcaster.

August 2014 – several stories ran in newspaper and on-line outlets around the world covering research published by Hinch and Cooke labs (Burnett et al. 2014 Physiological and Biochemical Zoology, 87(5): 587-598) which showed that sprinting salmon were more likely to perish enroute to spawning grounds than slower swimmers (Vancouver Sun, Winnipeg Free Press, The Province (Vancouver), Metro News (Vancouver BC), The Daily Courier (Kelowna BC), Ottawa Citizen, Nature World News, Austrian Tribune, Venezuela Star, Outdoor Life, Common Sense Canadian, Fish Farm News and Science, FiS Canada, The Fish Site, Science

c) Invited or contributed presentation/contribution at a workshop

Banet, A. I. (2014) Effects of maternal stress on offspring performance and behaviour in Pacific salmon. 6th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 6 2014.

Bass, A. L., Teffer, A. K., Cooke, S. J., Farrell, A. P., Miller, K. M., and Hinch, S. G. (2014) Chinook salmon migration following a fishery encounter. 5th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 6 2014.

Bass, A. L., Teffer, A. K., Cooke, S. J., Farrell, A. P., Miller, K. M., and Hinch, S. G. (2014) Chinook salmon migration following a fishery encounter. Lower Fraser Fisheries Alliance. Chilliwack, British Columbia. May 29, 2014.

Bett, N., and Hinch, S. G. (2014) Olfaction and homing in sockeye and pink salmon. 6th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 6, 2014.

Braun, D. C., McCubbing, D., and Hinch, S. G. (2014) Passage success of fishway naïve vs. non-naïve sockeye and population level enumeration. 6th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 7 2014.

Burnett, N. J., Hinch, S. G., and Cooke, S. J. (2014) Effects of dam-altered flow regimes on the swimming activity, behaviour and survival of adult sockeye salmon. Salmon Migration Workshop, University of British Columbia, Vancouver, Canada. February 6, 2014.

Cook, K. V., Drenner, S. M., Raby, G. D., Hinch, S. G., and Cooke, S. J. (2014) Factors influencing the fate of fish released from fisheries: Mortality of coho salmon bycatch rom Area 20 purse seine fisheries. Lower Fraser Fishery Alliance Technical Meeting. Richmond, BC, May. 29, 2014.

Furey, N. B. (2014) Movement behaviours and survival of outmigrant sockeye salmon across freshwater and marine landscapes. 6th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 6, 2014.

Furey, N. B., Hinch, S. G., and Lotto, A. G. (2014) Tracking Chilko sockeye salmon smolts during migration. Tsilhqot'in Nation Government Fisheries Forum. Williams Lake, British Columbia. March 10, 2014.

Harrison, P. M., Gutowsky, L. F. G., Martins, E. G., Patterson, D. A., Leake, A., Cooke, S. J., and Power, M. (2014) Personality-dependent spatial ecology of burbot, Lota lota, in a large hydropower reservoir in British Columbia, Canada. NSERC HydroNet 4th Annual Symposium, Vancouver, BC. April 28 to May 2, 2014.

Hinch, S. G., Bett, N., Burnett, N., Casselman, M., and Middleton, C. (2014) MON-14: Salmon migration in the Seton-Anderson watershed. Bridge-Seton Water Use Plan Monitoring Administrative Spring Workshop. Lillooet, Canada. May 5, 2014.

Langford, M., Martins, E. G., and Zhu, D. Z. (2014) Utilizing computational fluid dynamics to assess the hydraulic impacts of operations on resident fish at Mica Dam. NSERC HydroNet 4th Annual Symposium, Vancouver, BC. April 28 to May 2, 2014.

Martins, E. G., Hinch, S. G., Cooke, S. J., Farrell, A. P., Miller, K. M., and Thomson, R. E. (2014) A synthesis of salmon tracking studies in the Pacific Arena. Ocean Tracking Network Canada Fourth Symposium. Ottawa, ON. June 3-5, 2014.

Martins, E. G., Gutowsky, L. F. G., Harrison, P. M., Langford, M., Jonsen, I. D., Mills-Flemming, J. E., Leake, A., Patterson, D. A., Zhu, D. Z., Power, M., and Cooke, S. J. Behavioural attributes of entrainment risk for adult bull trout in Kinbasket Reservoir, B.C. NSERC HydroNet 4th Annual Symposium, Vancouver, BC. April 28 to May 2, 2014.

Middleton, C., Hinch, S. G., Martins, E. G., Braun, D. C., Burnett, N. J., and Casselman, M. T. (2014) Examining the effects of home-stream dilution and hydropower generation on Pacific salmon migration in a regulated system. 5th annual workshop on Salmon Migrations, Climate Change, and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 7.

Raby, G. D., Clark, T. D., Bett, N. N., Wilson, S. W., Willmore, W. G., Hinch, S. G., Farrell, A. P., and Cooke, S. J. (2014) Effects of water temperature and stressor duration on physiological recovery of coho salmon from fisheries capture. 6th annual workshop on salmon migrations, climate change, and capture/release fisheries. University of British Columbia, Vancouver, BC, February 6, 2014.

Sopinka, N. M., Patterson, D. A., and Hinch, S. G. (2014) Intergenerational effects of stress in sockeye salmon. 5th Annual Workshop on Salmon Migrations, Climate Chance and Capture/Release Fisheries. University of British Columbia. Vancouver, British Columbia. February 6, 2014.

Teffer, A. K., Miller, K., Farrell, A., Cooke, S., Jeffries, K., Juanes, F., and Hinch, S. (2014) Adult salmon (Oncorhynchus spp.) survival and disease potential under multiple stressors. UBC Workshop: Salmon Migrations, Climate Change and Capture/Release Fisheries, Vancouver, B.C. February 6, 2014.

Teffer, A. K., Miller, K., Donaldson, M., Cooke, S., and Hinch, S. (2014) Post-release survival of Early Stuart sockeye (Oncorhynchus nerka) after simulated encounter(s) with Chinook fisheries gear. Lower Fraser Fisheries Alliance Executive Committee Meeting, Sumas First Nation, Abbotsford, B.C. February 21, 2014.

Teffer, A. K., Miller, K., Donaldson, M., Cooke, S., and Hinch, S. (2014) Post-release survival of Early Stuart sockeye bycatch in a Chinook gillnet fishery. Lower Fraser Fisheries Alliance Technical and Science Forum, Squiala First Nation, Chilliwack, B.C. May 29. 2014.

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

Furey, N. B., and Hinch, S. G. (2014) Examining factors affecting the migration ecology of Pacific salmon smolts. Forest and Conservation Sciences Seminar Series, University British Columbia, Vancouver, British Columbia, Canada January 22, 2014.

Hinch, S. G. (2014) Changing climate and changing behaviour: using physiological telemetry and experimental biology to examine a conservation crisis in migrating adult Pacific salmon. Fisheries Centre Seminar Series (and FISH 500 grad course), University of British Columbia, Vancouver, BC, Sept. 12, 2014.

McLean, M. F. (2014) All things Acipenseridae. Biology Seminar, Dalhousie University, Halifax, Nova Scotia, Canada, January 2014.

Middleton, C., Hinch, S. G., Martins, E. G., Braun, D. C., Burnett, N. J., and Casselman, M. T. (2014) Examining the effects of home-stream dilution and hydropower generation on Pacific salmon migration in a regulated system. UBC Fisheries Centre weekly seminar series. February 28, 2014.

e) Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, and/or Glider runs, as well as a contribution to a larger piece of work in any of the former

Casselman, M. T., Burnett, N. J., Bett, N. N., Middleton, C. T., Martins, E. G., Braun, D. C., McCubbing, D., and Hinch, S. G. (2014) 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 – 2013. Report prepared for St'át'imc Government Services and BC Hydro. The University of British Columbia, Vancouver, BC. 66 p. + 2 Apps

Rechisky, E. L., Furey, N. B., Hinch, S. G., Porter, A. D, Clark, T. D., Gale, M. K., Jeffries, K. M., Casselman, M. T., Lotto, A. G., Middleton, C. T., and Welch, D. W. (2014) Assessing river and coastal ocean survival and movement rates of Chilko Lake sockeye salmon smolts: 2013 study. Final Report to the Pacific Salmon Foundation. 20 pages.

Rechisky, E. L., Welch, D. W., Porter, A. D., Furey, N. B., and Hinch, S. G. (2013) Telemetry-based estimates of early marine survival and residence time of juvenile Sockeye Salmon in the Strait of Georgia and discovery passage, 2013. Pages 213-127 in Perry, RI (ed). State of physical, biological, and selected fishery resources of Pacific Canadian marine ecosystems in 2013. DFO Can. Sci. Advis. Sec. Res. Doc. 3102. Available at http://www.dfo-mpo.gc.ca/Library/353469.pdf

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

June 2014 – McLean contributed her recapture data (PIT tag) from the White sturgeon tagging project to the Fraser River Sturgeon Conservation Society (FRSCS) White sturgeon recapture database. The FRSCS is a non-profit stewardship led conservation society.

g) Data deposition to OTN Data Centre

2014 acoustic receiver deployment metadata and detection data for Chilko River receivers and lower Fraser River receivers were deposited, as well as accompanying tagging data from project 4.15 and 4.12.

h) Invited or contributed consultation with an agency; public or private

Farrell met with aquaculture industry representatives several times throughout the year to solicit their collaboration in a project (OTN linked and leveraged) to monitor wild fish passage near open net-pen farms.

Farrell met with aquaculture Pacific Salmon Commission representatives several times throughout the year to solicit their collaboration in a project (OTN linked and leveraged) to monitor wild fish passage near open net-pen farms and to monitor general fish survival in the Salish Sea.

Hinch and Farrell met with the Pacific Salmon Foundation to discuss funding smolt telemetry research.

Miller met with hatchery managers within the Salmon Enhancement program to solicit their collaboration in our Genome BC (OTN linked and leveraged) funded project; hatcheries agreed to collect relevant material in support of this program in April, 2014.

i) Books

Sopinka experience with winning the UBC Three Minute Thesis competition (3MT) is featured in the book chapter:

Beard, E. L., and Wilson, S. M. (2014) Make a Science of Communication In "Future of Fisheries: Perspectives for Emerging Professionals". Eds (Taylor, W.W., Lynch, A.J., Léonard, N.J). American Fisheries Society.

k) Internet publishing, portal, blog, electronic publications

May 28, 2014 – The Williams Lake Tribune published an article online titled "Chilko super fish make run to the ocean" highlighting the Chilko sockeye salmon outmigration, including mention of OTN researchers tracking the migration through tagging. [http://www.wltribune.com/news/260953791.html].

June 3-5, 2014 - Sopinka live-tweeted the OTN annual conference in Ottawa on Twitter and compiled the tweets into an online summary or Storify; link: https://storify.com/phishdoc/ocean-tracking-network-2014.

October (to present) 2013 - 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.

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

Furey was asked to provide a profile on his research on outmigrant sockeye salmon smolts by the American Fisheries Society (AFS) after being selected as an Honourable Mention for the Steven Berkeley Marine Conservation Fellowship through AFS (July 2014). His profile will be included in an upcoming issue of AFS magazine Fisheries.

Sopinka, Cook and Teffer were 2013-2014 Executive Committee members 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.

McLean's experience at the 5th International Bio-logging Science Symposium was featured in the Ocean Tracking Network News Bulletin (2014).

McLean provided details on her thesis and OTN-related research to interested 2nd year students at the BC Institute of Technology.

Cooke provides routine updates on several OTN Pacific Arena members and their activities through Twitter (@SJC_Fishy).

Cook and Teffer accepted a shared student representative position on the UBC Animal Care Committee.

Cook organised a symposium at the Western Division American Fisheries Society meeting in Mazatlan, Mexico entitled, "the Fate of fish released from fisheries: Issues and solutions."

Cook served on the organizing committee at the Western Division annual meeting in Mazatlan Mexico and organised volunteer judges for best student presentation and poster.

Cooke organized a symposium at the AFS Quebec City meeting on the state and future of freshwater fisheries science in Canada.

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

Furey competed for and won a Fisheries Society of the British Isles (FSBI) Small Research Grant (value = 5,000 £; awarded March 2014) to study movements of predatory bull trout during sockeye salmon smolt outmigration by leveraging OTN equipment that was being concurrently used for OTN project (4.15) (Chilko sockeye salmon telemetry project). Project title: "Movements and behaviours of bull trout (*Salvelinus confluentus*) during an annual prey pulse of outmigrant sockeye salmon (*Oncorhynchus nerka*) in relation to spatiotemporal heterogeneity in prey availability and water temperature." Furey led this fieldwork in April-May 2014, and the funding continues to 2016. Some of this research has led to new collaborations between Furey, and Drs. Joanna Mills-Flemming, Ian Jonsen, and Eduardo Martins.

Hinch, Furey, Miller and Cooke submitted a proposal to the Pacific Salmon Foundation (~$500,000) to continue to examine the physiology, behaviour and survival of Fraser River salmon smolts using physiological telemetry. This work builds off of OTN Pacific project 4.15 and would continue it for another three years. The OTN, through its CFI infrastructure funds, has agreed to loan 35 VR4s to this endeavour as leverage, and project 4.15 can provide some in-kind support via personnel and equipment.

Hinch and Furey submitted a proposal to BCHydro (~$750,000) to examine the survival of out-migrating smolts through its Seton River powerhouse station using telemetry over three years. This work leverages the expertise and infrastructure we have developed through project 4.15.

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

Furey has supplemented his fieldwork 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 recently accepted at the Journal of Fish Biology. 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.

Raby was invited to take part in a collaborative research trip to Lizard Island Research Station (Australia) on the Great Barrier Reef (GBR, Aug 22 – Sept 11). With support of an OTN HQP travel grant he was awarded, he spent three weeks at Lizard Island doing research funded by OTN collaborator Dr. Tim Clark (now at the Australian Institute of Marine Science). The research Graham conducted while there was built on expertise he developed while part of OTN working in the Pacific Arena. While at Lizard Island, he used videography to assess the impacts of catch-and-release fishing on behaviour of GBR fishes. Graham also used accelerometer loggers to understand fine-scale behavioural differences among coral trout and the connection between those differences and vulnerability to angling.

Martins, Cooke and Power are actively participating in the extension of OTN activities in Brazil, particularly in the Brazilian Amazon. The researchers will meet with other OTN members and several Brazilian researchers in Brazil in February 2015 during the conference of the Brazilian Society of Ichthyologists, where they will discuss the expansion of the network in the country.

Eduardo Martins was recently awarded a Liber Ero Fellowship to conduct research on the effects of multiple stressors and management actions on the viability of Fraser River sockeye salmon. The 2-year research will build on historical databases maintained by DFO and other agencies, as well as telemetry data that have been collected by the OTN Pacific Arena.

Bett assisted in a research study (lab of D. Close at the University of British Columbia November, 2013) that explored the effects of carbon dioxide tension on the olfactory abilities of coho salmon. The study was a spin-off of Bett's field research.

Miller has been collaborating with Ian Fleming and Fred Whoriskey conducing genomic analyses on some of their recent kelt tissue samples for microbes. Whoriskey is now considering doing more sampling, as Miller did find one particularly pathogenic microbe in high prevalence in his out-migrating smolts.

o) 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

McLean is currently developing a method for the implantation of leadless heart loggers for use in white sturgeon.

The microbe monitoring platform development and evaluation was completed (funded by Genome BC project that is linked and leveraged with OTN Canada). This platform makes it possible to assess the presence and load of 46 salmon pathogens on non-destructively sampled tissue from tagged fish. We had already applied this platform preliminarily in the 2014 Miller publication in Evolutionary Applications (a solicited manuscript). We now have performed the validations that show the sensitivity, specificity and repeatability of results from this platform, providing assurance that the data produced are of high quality and accuracy. This platform may very well revolutionize our understanding of the role of pathogens, and more explicitly, co-infections, on wild salmon performance.

p) 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.

Raby traveled to Lizard Island Research Station and conducted the first study using external "backpack"-style attachment of accelerometer loggers in coral trout, providing a proof-of-concept for the species. Those data will help understand inter-individual differences in activity rates in coral trout and expand the toolkit used to assess behavioural types in wild coral reef fishes.

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.

q) 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 of the Chilko Lake sockeye salmon smolt migration study, approximately 200 smolts were collected 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.

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

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.

The Fisheries Society of the British Isles provided a grant to Nathan Furey (OTNC PhD student) specifically to enhance the study of Chilko Lake sockeye smolts.

b) Contributions

Name of supporting organization: **DFO Pacific Region**	**Year 5** (2014)
Cash contributions to direct costs of research	$0
In-kind contributions to direct costs of research	
43) Salaries for scientific and technical staff	$64,900
44) Donation of equipment, software	$34,800
45) Donation of material	$8,000
46) Field work logistics	
47) Provision of services	
48) Other (specify):	
In-kind contributions to indirect costs of research	
22) Use of organization's facilities	
23) Salaries of managerial and administrative staff	
24) 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 5** (2014)
Cash contributions to direct costs of research	$0
In-kind contributions to direct costs of research	
31) Salaries for scientific and technical staff	$28,750
32) Donation of equipment, software	
33) Donation of material	
34) Field work logistics	
35) Provision of services	
36) Other (specify):	
In-kind contributions to indirect costs of research	
16) Use of organization's facilities	
17) Salaries of managerial and administrative staff	
18) Other (specify):	
Total of all in-kind contributions	$28,750
Is this new funding (acquired during this reporting period)?	no

Name of supporting organization: **Fisheries Society of British Isles**	**Year 5** (2014)
Cash contributions to direct costs of research	$9,600
In-kind contributions to direct costs of research	
19) Salaries for scientific and technical staff	
20) Donation of equipment, software	
21) Donation of material	
22) Field work logistics	
23) Provision of services	
24) Other (specify):	
In-kind contributions to indirect costs of research	
10) Use of organization's facilities	
11) Salaries of managerial and administrative staff	
12) 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 5 Review: 1 October 2013 – 30 September 2014

1. Project Number: 4.16

2. Project Title: Networking, HQP Exchange and Social Science Components

3. Project Leaders: S. Iverson, S. Cooke, A. Fisk, K. Fennel, I. Fleming, S. Hinch, S. Vagle

Other OTN Canada participants: all other OTN Canada PIs
Collaborators: Fred 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 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. Recent symposia have broadened networking opportunities by including members of the International Scientific Advisory Committee, international HQP, and invited speakers. These Symposia have been tremendous successes – each one has resulted in a leap-frogging of activities, coordination and effectiveness of the Network. The fourth annual OTN Canada Symposium (described further in section 4.17) featured a stipulation that one third of HQP presentations (posters and talks) must address examples of intranetworking. HQP exceeded expectations of this requirement to demonstrate a cohesive and highly effective and collaborative research network. Workshops also trained or introduced participants to important issues including new technology, animal handling and tagging methods, data management, and data analysis and visualization tools. A synthesis of HQP presentations was compiled and is hosted on the OTN website under a private section dedicated to information relevant to the OTN Canada Network.

5. Networking, travel, and training of Highly Qualified Personnel

c) Travel and conference attendance (HQP, PI's, and collaborators)

OTNC HQP, PI	Conference
Amy Teffer	International Symposium on Aquatic Animal Health
Amy Teffer	International Congress of the Biology of Fish
Amy Teffer	Western Division of the American Fisheries Society Annual Meeting
Arthur Bass	Ecological and Evolutionary Ethology of Fishes Conference
Colin Buhariwalla	American Fisheries Society Annual Meeting*
Collin Middleton	International Conference on Engineering and Ecohydrology for Fish Passage
Damian Lidgard	The 5th Bio-logging Science Symposium
David Yurkowski	Field work on Sable Island - capturing
Edmund Anthony Halfyard	American Fisheries Society 144th Annual Meeting
Eduardo Martins	XXI Encontro Brasileiro de Ictiologia
Eduardo Martins	Symposium on Animal Movement and the Environment
Eduardo Martins	American Fisheries Society 144th Annual Meeting
Franziska Broell	The 5th Bio-logging Science Symposium (BLS5)
Franziska Broell	International Congress on the Biology of Fish*

Franziska Broell	American Fisheries Society Annual Meeting*
Graham Raby	Collaborative field project - conservation physiology of Great Barrier Reef fishes
Jacqueline Chapman	International Congress of the Biology of Fish
Jean-Sebastien Moore	Workshop and community consultations Edmonton
Jean-Sebastien Moore	Conference
Jeffrey Beardsall	White Sturgeon Backpack Development and Testing
Jeffrey Beardsall	American Fisheries Society 144th Annual Meeting*
Julian Dodson	American Fisheries Society Annual Meeting*
Katrina Cook	Western Division American Fisheries Society Annual Meeting
Kenneth John Lohmann	American Fisheries Society 144th Annual Meeting
Kyle McKenzie	American Fisheries Society 144th Annual Meeting
Kyle McKenzie	Coastal Zone Canada 2014 Conference
Laura Logan Chesney	American Fisheries Society Annual Meeting*
Laurie Baker	International Statistical Ecology Conference
Maria Cecilia Engler-Palma	Coastal Zone Canada 2014 Conference
Martin Castonguay	American Fisheries Society Annual Meeting*
Mathieu Dever	144th American Fisheries Society annual meeting
Mathieu Dever	Ocean Science Meeting
Melanie Beguer	American Fisheries Society 144th Annual Meeting
Mike Donaldson	American Fisheries Society 144th Annual Meeting*
Mike Stokesbury	American Fisheries Society Annual Meeting*
Montana F. McLean	The 5th International Bio-logging Science Symposium
Natalie Sopinka	Washington-British Columbia Chapter of the American Fisheries Society 2014 AGM
Natalie Sopinka	Ecological and Evolutionary Ethology of Fishes
Nich Burnett	International Conference on Engineering and Ecohydrology for Fish Passage
Nolan Bett	NSERC HydroNet Symposium*
Nolan Bett	International Conference on Engineering and Ecohydrology for Fish Passage
Nolan Bett	Ecological and Evolutionary Ethology of Fishes
Scott Hinch	International Congress of the Biology of Fish
Shiliang Shan	144th American Fisheries Society Annual Meeting: International Eel Symposium 2014
Steve Cooke	International Congress of the Biology of Fish
Taylor Ward	International Congress of the Biology of Fish
Vanessa Minke-Martin	2014 Ecological and Evolutionary Ethology of Fishes
Vivian Nguyen	Pathways 2014 Common Futures: integrating human dimensions into fisheries and wildlife management
Vivian Nguyen	American Fisheries Society 144th Annual Meeting
Vivian Nguyen	Coastal Zone Canada 2014 Conference

**Not OTNC funded, but demonstrated positive contributions/impacts to the OTN.*

***Note: While funding for some of the conference travel listed here was provided by other sources, OTN Canada provided approximately $50K for travel to national and international conferences, meetings, and workshops, and over $20K in support of HQP travel to the OTNC Annual Symposium. A list of 2014 OTNC Symposium attendees (81 total; 46 HQP) can be found as an appendix* (Appendix A).

d) HQP and level of support

Name	Title	% Time in project	% Support from OTNC	Start Date	End Date
Nathan Young	choose				
Research Topic: Pacific salmon commercial and First Nations fisheries: delayed mortality, behavior and physiology of released bycatch in coastal waters					
Mike Reid	RA			1-Sept-2014	30-Nov-2014
Research Topic: Atlas Project					

Shane Beblin	choose			3-May-2014	6-Sept-2014
Research Topic: Pacific sturgeon law and policy					

6. Progress towards objectives/milestones

f) Overall objectives

- HQP exchanges and selected conference attendance
- Further integration of OTN social sciences

g) Progress

Given the immense importance of the Annual Symposia and specialized workshops to the advancement of OTN Canada and 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 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. In addition to funding 46 HQP to attend the annual June Symposium, since March 2014 the TAC has processed 16 HQP travel requests to various national and international conferences, workshops and collaborative fieldwork. Travel conducted throughout this reporting period is summarised in the table above. Following conference attendance, HQP are required to draft a short follow-up describing their experience and benefit to the network. These reports are shared in the "NSERC Network" section of the OTN website with a view towards sharing information and resources gained from these conferences.
- Thirty-five (35) HQP attended national and international conferences and workshops during the reporting year in an effort to broaden their training and skills, and enhancing value to the Network.

Further OTN social science integration

- Talks began in August with Dalhousie University social scientist Claudio Aporta (Associate Professor, Marine Affairs) regarding the creation of an interactive atlas using OTN data sets. The purpose of the atlas is to broaden awareness of OTN activities for public interest and education, and ultimately as a tool for policy. Several discussions took place and a proposal for this project is being presented at the December SAC meeting to discuss further funding of this project to its completion. Preliminary work on the atlas concept was granted funding approval by the OTN Reprofiling Committee (described in section 4.16) for the work of RA, Mike Reid.
- Nathan Young joined the social science contingent of OTN Canada in 2013. N. Young leads a social science project within 4.12 (Pacific salmon commercial and First Nations fisheries: delayed mortality, behaviour and physiology of released bycatch in coastal waters) that addresses issues associated with knowledge transfer and application by users of Pacific salmon. N. Young has also authored works in a special issue of the *Journal of International Wildlife Law & Policy* focusing on social science issues within Ocean Tracking Network studies.
- Jesse Web (UNB) continued to work on the sturgeon project (and will do so this year as well). *

- Shane Beblin worked for OTN on the Pacific sturgeon law and policy in collaboration with Glenn Crossin and his group (Project 4.14).
- Tsafrir Gazit worked until June 30 on grey seal (several manuscripts are in the editing phase), sociology of knowledge and the forming of the network (with R. Apostle), and Atlantic and pacific sturgeon (with D. VanderZwaag, R Apostle) projects, as well as various projects on data management and data policy (with R. Branton and others). *
- D. VanderZwaag continues to work on the Australian connection with a possible workshop in early 2015. Initial discussions were held with various Australian ocean tracking and management researchers regarding a proposed project linking OTN Canada with OTN Global, where Canadian and Australian approaches and challenges in tracking and sustaining marine species at risk would be compared. A research proposal has been submitted to the Australian Research Council with an expected decision in early November. *
- A book (edited by Harry N. Scheiber) with selected papers from the "Science, Technology, And New Challenges To Ocean Law" October 11-12, 2013, Berkeley, CA conference will be published this year including a paper authored by D. VanderZwaag entitled "Sustaining Atlantic Marine Species at Risk: Scientific and Legal Coordinates, Sea of Governance Challenges." The book title is undecided yet. *

** Note: Ongoing work from OTN Phase I; no longer funded in Phase II*

h) Significant deviations

No significant deviations were experienced this year.

7. Difficulties encountered

☒ No problems occurred during the reporting period

8. Networking and outreach

c) Intra-network collaboration and partner meetings

The various social, legal, and natural scientist research teams have been working closely together on their respective case studies, as above (section 6b). This includes routine meetings and discussions, and in some cases, social scientists have accompanied natural scientists and HQPs in the field.

The majority of the Networking, HQP exchange, and social science component project leaders, OTN PIs, and collaborators attended the fourth annual OTN Canada Symposium in Ottawa (3-5 June).

d) Interaction/Outreach to Broader Community

Members of the OTN social science group presented their case studies during a special session ("From Science to Governance: Ocean Tracking Research for the Betterment of Canadian Marine Ecosystems and Resource Management") at the Coastal Zone Canada Conference in June 2014. The case studies were drawn from a special two-part issue [16(2–3) and 16(4)] of the *Journal of International Wildlife Law & Policy]*, examined OTN Canada's research on American eel, Atlantic sturgeon, grey seal—Atlantic cod interaction, and Pacific salmon. The first three case studies presented by pairs of

researchers highlighted the scientific advances in tracking marine species and the ongoing governance challenges. A single researcher who is attempting to bridge the gap between the natural and social sciences within her own research presented the fourth case study.

9. Dissemination of information and results

e) Conference presentations (6 total) – invited

Apostle, R. (2014) The Making of a Global Network II: The Ocean Tracking Network Takes Shape, 2010-2013. International conference on science in society, UBC Robson square, Vancouver, Canada.10-11 October 2014.

Béguer-Pon, M., VanderZwaag, D.L., Dodson, J.J., and Castonguay, M. (2014) Sustaining American Eels: A Slippery Species for Science and Governance. Coastal Zone Canada 2014 Conference, Halifax, NS. 16 June 14.

Iverson, S. J. (2014) The Ocean Tracking Network (OTN): Natural Science & Technology. Coastal Zone Canada 2014 Conference, Halifax, NS. 16 June 14.

Iverson, S. J. and Gazit, T. (2014) From Science to Governance: Grey Seals & Atlantic Cod. Coastal Zone Canada 2014 Conference, Halifax, NS. 16 June 14.

Litvak, M., Apostle, R., and Engler, C. (2014) OTN Case Study: Atlantic sturgeon. Coastal Zone Canada 2014 Conference, Halifax, NS. 16 June 14.

Nguyen, V. M, Young, N., and Cooke, S. J. (2014) From Science to Governance: Ocean Tracking Network Pacific Salmon Case Study. Coastal Zone Canada 2014 Conference, Halifax, NS. 16 June 14.

VanderZwaag, D. L. and Apostle, R. (2014) OTN: The Social and Legal Dimensions. Coastal Zone Canada 2014 Conference, Halifax, NS. 16 June 14.

Ocean Tracking Network Canada **NSERC**
Progress Report Year 5 Review: 1 October 2013 – 30 September 2014

1. Project Number: 4.17

2. Project Title: Ocean Tracking Network Canada Secretariat

3. Project Leaders: S. Iverson (Scientific Director), K. McKenzie/Amy Ryan (Network Manager), N. Beauchamp (Communications and Public Relations) (Dalhousie)

4. Staff

Name	Title	% Time in project	% Support from SNG	Dates
Sara Iverson	Scientific Director	80	0	1 Oct 2013 - 30 Sep 2014
Kyle McKenzie (Amy Ryan)	OTN Canada Network Manager (Acting Network Manager as of October 2014)	100	100	1 Oct 2013 - 30 Sep 2014
Nikki Beauchamp	OTN Communications and Public Relations	100	100	1 Oct 2013 - 30 Sep 2014
Tracy Rounds	OTN Administrative Asst	50	0	1 Oct 2013 - 30 Sep 2014
Kes Morton	OTN Senior Project Manager	25	0	1 Oct 2013 - 30 Sep 2014
Timothy Arrott	2014 Summer Co-op Student	100%	100%	26 Apr 2014 – 7 Aug 2014

5. Progress towards objectives/milestones

a) Overall objectives

The main objectives of the Secretariat in Year 5 are as follows:

i) Office operation and human resources

- Participate in regular NSERC Network and OTN Global management 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 (NSERC Form 300 to be provided by Dalhousie Financial Services)

iii) Committees, meetings, symposia, workshops, and outreach

- Organize and host 4th OTN Canada Symposium
- Organize Annual SAC and Arena Leaders meetings/conference calls
- 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 2013-2014
- Together with the larger OTN secretariat, produce a glossy public annual report on noteworthy activities in 2014 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

- Revise/merge and populate the OTN Canada and OTN Global websites
- Produce a newsletter to be distributed to OTN, sponsors, and related 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 fifth 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 SNG 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 (Fred 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 Manager (Kyle McKenzie; Amy Ryan, acting NM as of October 2014);, the Communications/PR (Nikki Beauchamp), and the OTN Administrative Assistant (Tracy 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, 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 bi-monthly, 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;

- chairs 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;

In addition to regular committees, together with F. Whoriskey and K. Morton, S. Iverson met throughout the report year with contractors and Dal VPs and AVPs on the design and construction of ongoing new OTN headquarters space in the Steele Ocean Sciences Building. 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).

Kyle McKenzie* has been the Network Manager for the OTN Canada Network. The Network Manager assists the Scientific Director in overseeing all administrative management of the NSERC Network and in outreach of the Network, and in engaging it with other relevant networks. He reports to the Scientific Director of OTN Canada and the Executive Director of OTN. As Network Manager, he serves on the following committees:

- the OTN Secretariat
- the OTN Status Committee
- the OTN Management Committee
- the OTN Canada SAC;
- the OTN ISAC; and
- the OTN Council

* A. Ryan stepped in as acting Network Manager on 1 Oct 2014, following request for extended leave by K. McKenzie and as such, duties and responsibilities were reorganized.

Nikki Beauchamp is the Communications Manager for all OTN. She manages all media relations as well as web site and social media content; newsletter and public annual report production as well as strategic communications opportunities as they arise. 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.

Tracy Rounds is the OTN 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.

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 (replacing J. Cullen (ret'd)), 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.

Two requests were made to the Reprofiling Committee in 2014: one allocation for Mike Reid, PhD student to social scientist Claudio Aporta (Dalhousie), for help with development of a prototype of an

interactive, web-based Atlas using OTN data, which could potentially be a powerful integrative tool as OTN goes forward (to be presented to the SAC for further funding); the other request was for an honorarium to summer co-op student Tim Arrott, who stayed on as a volunteer after the end of his co-op position to develop a mobile application to help taggers record and transmit field metadata back to headquarters.

HQP Travel Approval Committee. This subcommittee was organized on the recommendation of the SAC during the 2013 meeting. It is comprised of OTN Canada PIs Glenn Crossin, Scott Hinch, Matt Litvak, and Svein Vagle, with N. Beauchamp to act as liaison (formerly K. McKenzie). This committee reviews and approves or rejects HQP travel applications up to $5K, but normally about ~$1.5K (as determined by the SAC). Exceptions may be made to this figure with the endorsement of PIs.

Other financial matters. In the report year (beginning Jan 2014), for the first time, Dalhousie allowed the NSERC network grant to be split among most individually managed and budgeted projects within Dalhousie. Specifically, projects 4.1, 4.2, 4.3, 4.4, 4.7, 4.8 and 4.14 have their own accounts, as does the Secretariat (4.17). All other funds covering networking, HQP exchange and social science components, as well as all institution transfers reside in the main account. This is beginning to make budget keeping for S. Iverson less complicated and time-consuming.

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.

The Secretariat organized the 4th annual OTN Canada Symposium and associated workshops, and three SAC meetings (two in Halifax and one by teleconference), and an Arctic strategy meeting, as well as proposed several major academic meetings for next year. As the network is maturing and running more effectively, we are trying to reduce administrative meetings, but as complexity of the network grows, so also do new issues requiring attention. Secretariat staff were responsible for producing the agenda, arranging presentations, making extensive logistical arrangements, communicating the information regarding the meetings to the OTN Canada network, preparing the information to be listed on the web site, and producing minutes and summaries.

AAAS 2014. OTN hosted a special session in February 2014, 'The Ocean Tracking Network: Global Innovation in Technology, Science, and Management Symposium,' on OTN's Canadian and international studies, as well as data management, and social science and policy initiatives. Speakers S. Iverson, S. Cooke, Z. Willis (U.S. IOOS; NOAA), K. Holland (U Hawaii), and P. Harrison (OTN Council Chair) offered presentations on specific areas of work within OTN.

OTN Brazil 2014. S. Iverson co-organized a workshop in Rio Grande, Brazil in April 2014 in co-ordination with D. Webber from Vemco. This workshop introduced many Brazilian investigators to OTN and to Vemco technologies and equipment use. This was followed by 5 other mini-workshops and seminars given by S. Iverson along with Brazilian collaborators through eastern Brazil in April and May 2014.

Fourth Annual OTN Canada Symposium in Ottawa. The purpose of the OTN Canada symposia are to bring together all students, PDFs, and PIs to present projects and results, discuss research strategies, and focus on integration of the NSERC Network and sharing of research tools and programs within and across Arenas. For the second year in a row and continuing forward, this event has been open to invited

international HQP, ISAC and Council members, other network collaborators, and the public. The 4th annual OTN Canada Symposium was held in Ottawa, ON, primarily to accommodate a special reception on Parliament Hill. During the symposium, S. Iverson announced the integration of the OTN-hosted 3rd International Conference on Fish Telemetry and the annual OTN Canada Symposium. The symposium agenda was carried out as usual with the exception of a special panel hosted to discuss the future of the Network.

OTN Parliamentary Reception (Ottawa). A special reception was co-hosted with the All-Party Oceans Caucus as a way of introducing OTN and its activities to Canadian MPs and Senators. Over 30 MPs attended the reception, which was also attended by members of the SAC, ISAC, Council and selected OTN Canada HQP. S. Iverson, P. Harrison (OTN Council Chair) and M. Crago (VP Research, Dalhousie) gave remarks. The OTN glider and tracking equipment were showcased and garnered significant interest.

Oceans of Opportunity Workshop. Mutual goals, shared resources, effective outcomes (Ottawa). K. Morton and N. Beauchamp led the successful application for a $25K NSERC grant to promote networking among members of government, industry, and academia during a full-day workshop. The workshop involved key members of the aforementioned sectors (including OTN members) working to identify collective resources and major capital assets, document existing collaborations, and identify industry needs and interrelate them to ocean infrastructure towards building better partnerships and collaborations. A long-term outcome of the workshop is the regular interaction of communications personnel of the major oceans-research networks in Canada (OTN, ONC, ArcticNet, MEOPAR) led by N. Beauchamp.

Coastal Zone Canada 2014. K. McKenzie, in conjunction with members of the governance research team, hosted a half-day OTN-themed session entitled "From Science to Governance: Ocean Tracking Research for the Betterment of Canadian Marine Ecosystems and Resource Management" at the Coastal Zone Canada conference in June 2014, in Halifax.

AFS 2014. With the help of Martin Castonguay (OTN Canada - DFO and Laval), OTN organized a telemetry symposium held at the American Fisheries Society annual meeting in Québec, Aug 17-21, 2014. Several OTN attended the conference and helped host a trade-show booth. HQP remarked the booth was a welcome "home base" during the conference.

Canadian Science Policy Conference 2014. S. Iverson and F. Whoriskey co-organized and participated in an OTN-led special session entitle "Big Problems, Big Networks, Big Data".

Brest, France Sept 2014. S. Iverson participated in a Dalhousie delegation to Brest, France (funded by the French Embassy) to present OTN and to discuss mutual collaboration and training opportunities with OTN.

SAC meetings. As a follow-up to the 2013 annual face-to-face SAC meeting in Vancouver in December 2013, the SAC held a meeting by teleconference in February 2014 to receive and approve amended annual reports for 2013 and budgets for 2014.

The 2014 annual face-to-face SAC Meeting is scheduled for 2-3 December in Halifax. The main objectives of this meeting are to review research progress of the Network, to approve Year 5 reports and budgets and review and approve proposed budgets for OTN Canada Phase II, as well as to discuss Phase II wrap up and future funding opportunities.

Fifth annual OTN Symposium 2015. Planning is underway by the OTN Secretariat for the 5th Annual OTN Symposium (15 July) to be held in conjunction with the 3rd International Conference on Fish Telemetry (ICFT, 13-17 July in Halifax). The timing is a tremendous opportunity for Network members, particularly HQP, to gain significant exposure to the international telemetry community and training during associated workshops. The Symposium will also utilize the same space and combine travel thus reducing overall cost for this annual meeting.

ICFT 2015. N. Beauchamp developed a detailed proposal to host the 3rd International Conference on Fish Telemetry in Halifax in 2015. Acceptance of this proposal was announced at the 2nd International Conference on Fish Telemetry in July 2013 and planning is underway led by 3rd ICFT co-chairs N. Beauchamp and K. Morton.

iv) Reports and Proposals

The annual progress report template was updated and distributed to PIs as a form to be completed by late October. Based on feedback from the SAC at the 2012 annual meeting, word limits were again 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 changed this year. S. Iverson has worked with PIs to match expenditures with the NSERC Form 300s from all institutions for January - September 2013, in an attempt 1) to make budget reporting more transparent/easier for the SAC to evaluate and 2) to determine total project carryovers from Phase I to help with budget request shortfalls for Phase II.

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.

OTN Global and OTN Canada are collaborating on an integrated annual report for noteworthy activities in 2014 (http://oceantrackingnetwork.org/docs/2013-otn-annual-report/at_download/file) to be released in December 2014.

Members of the Secretariat are working to build a library of publications related to the OTN and acoustic telemetry research using an existing online reference manager (i.e., Mendeley, RefWorks, etc.) that would be searchable by all OTN collaborators. A. Ryan and T. Rounds will be working together to build this library. T. Rounds is in the process of uploading the author-generated literature lists created from our annual reports. A. Ryan met with Michelle Paon, the Reference and Instruction Librarian at Dalhousie University, and Geoff Brown (Dalhousie librarian) to get advice on how to link the OTN main site to an online reference manager, run standard monthly searches of all relevant research databases so that our library will stay current, and run statistics that would allow us to generate information on our research outputs and collaborations, consequently contributing to the efficiency of the reporting process. Jonathan Pye (OTN Portal Manager) will be involved in creating visualizations with this dataset.

v) Website and newsletter

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 deployment, data, and technology updates as well as conference dates and calls for proposals. In fall 2014, the format and

schedule for newsletter production and distribution was revised towards increasing visibility and timeliness of news reporting and will appear on more frequent basis in shorter, more digestible format beginning in 2015. This and various website revisions will effectively replace 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. Hard copies are distributed during promotional events and to visiting delegations.

N. Beauchamp led the development of a new, integrative OTN Canada and OTN Global website referred to simply as the OTN main site. It features a modern layout, more streamlined navigation and updates, and is geared towards public interest and end-users (including Network members). Strategy for the new website and general online media involves frequent study of analytics towards a highly user-friendly experience and positioning OTN as a global leader in acoustic telemetry and marine animal tracking research both for academic and public consumption.

vi) Data management

A new International Data Management Committee (IDMC) was formed in July 2014. The ICDMC includes Kes Morton (OTN sr. project manager), Hassan Moustahfid (Integrated Ocean Observing System, U.S.), Fred Whoriskey (OTN executive director), 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). The IDMC works to:

- Oversee the OTN Data Plan
- Design 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 OTN data management team has developed a tool (the Mihoff-White False Filtering Tool) that will assist with filtering false animal detections on acoustic receivers. The original concept came from work done by Easton White who shared his resource library with OTN data managers. The proof of concept was presented to Steve Kessel and Eddie Halfyard in December 2013 and a decision was made to develop a tool for general use. The false filtering tool was presented during the OTN Symposium in Ottawa. Several webinars have been hosted through OTN to disseminate this tool to users not able to attend the symposium. A tutorial on the tool's installation is hosted on the OTN YouTube channel and the OTN website.

vii) Communication with OTN Global and funding partners

OTN Canada and OTN Global 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 and K. McKenzie attended and contributed to bi-monthly OTN Management Committee Meetings. Along with N. Beauchamp they also 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 good communication with other funding partners, which resulted in significant sponsorship of this year's annual symposium.

c) Significant deviations

No significant deviations were experienced this year.

d) Coordination and integration

See overall network report.

6. Difficulties encountered

☒ Personnel problems

While it was important for K. McKenzie to attend to personal issues, his extended leave, announced on 29 September effective immediately, was a sudden and difficult change in OTN staffing and work load, particularly in that it coincided completely in timing with the extensive duties associated with NSERC Annual Reporting. However, A. Ryan quickly assumed an acting role to take over many of these duties and everyone else within the Secretariat pitched in, and duties and responsibilities were reorganized to successfully tackle the workload. Nevertheless, project and budget reporting was difficult to complete in time for the annual SAC meeting and some delays were unavoidable.

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

Major intra-network collaboration activities (e.g. the annual symposium) 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.

8. Dissemination of information and results

a) *Refereed journal articles (0 total) – accepted/published*
b) *Refereed journal articles (0 total) – submitted*
c) *Conference presentations (0 total) – invited*

(See Project 4.7)

d) *Conference presentations (0 total) – contributed*

9. Other contributions and deliverables

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

In August, OTN was joined by Canadian comedian Rick Mercer for filming of a segment of the popular Canadian news-satire show *Rick Mercer Report* (CBC). The episode aired October 17 to very positive reviews. The seven-minute segment captured much of the blue shark tracking research (inlcuding handling practices, animal welfare) and a general overview of OTN (B. Davis, F. Whoriskey).

CBC's *Land and Sea* nature series also filmed the blue shark tracking study (B. Davis, F. Whoriskey) with much the same focus as the *Rick Mercer Report*. The 20-minute episode has yet to air.

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

N. Beauchamp presented an overview of the Ocean Tracking Network and its research/HQP roles to the Discovery Centre's *Tide to Tech* program launch aimed at high school students to bring awareness to careers in ocean science.

e) *Data reports, technical reports, manuscript reports, advisory documents, briefing notes, handbook or guide, checklist, barcode, CTD casts, and/or Glider runs, as well as a contribution to a larger piece of work in any of the former*

OTN (N. Beauchamp), produced the September issue of the science-policy brief *SciencePages*, which focused on oceans policy and management issues, and was presented during the October science-policy briefing event at which former OTN PI, J. Cullen (ret'd) was the invited expert.

q) *Other*

A mobile application was created by OTN volunteer, T. Arrott. The app is a mobile version of the Excel spread sheet format used to report tag metadata to OTN HQ. It ultimately streamlines collection and transmission of field tagging metadata to the OTN database by using smart-phone data (time, date, location) to pre-fill and batch-fill appropriate input fields. It also walks the user through the metadata-recording process for reduced workload and likely reducing manual-entry errors as a result of copying field notes into an Excel spreadsheet. The application automatically sends data to OTN field-ops and data acquisition co-ordinator, S. Dufault, in spreadsheet format. Some Network members (S. Kessel, C.

Buhariwalla), in addition to the OTN data acquisition coordinator, expressed interest in such an app. This app was developed with feedback from C. Buhariwalla and L. Logan-Chesney (Acadia).

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 4** (2013)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
49) Salaries for scientific and technical staff	
50) Donation of equipment, software	
51) Donation of material	
52) Field work logistics	
53) Provision of services	
54) Other (specify):	
In-kind contributions to indirect costs of research	
25) Use of organization's facilities	
26) Salaries of managerial and administrative staff	
27) 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:

- Bob Branton, Director of Data Management
- Susan Dufault, Data Manager

2) Provision of services through use of data management team and website assistance.

Name of supporting organization: **Department of Fisheries and Oceans**	**Year 4** (2013)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
37) Salaries for scientific and technical staff	
38) Donation of equipment, software	
39) Donation of material	
40) Field work logistics	
41) Provision of services	
42) Other (specify):	
In-kind contributions to indirect costs of research	
19) Use of organization's facilities	
20) Salaries of managerial and administrative staff	
21) 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 4** (2013)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
25) Salaries for scientific and technical staff	
26) Donation of equipment, software	
27) Donation of material	
28) Field work logistics	
29) Provision of services	
30) Other (specify):	
In-kind contributions to indirect costs of research	
13) Use of organization's facilities	
14) Salaries of managerial and administrative staff	
15) 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, K. McKenzie, 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 4** (2013)
Cash contributions to direct costs of research	
In-kind contributions to direct costs of research	
7) Salaries for scientific and technical staff	
8) Donation of equipment, software	
9) Donation of material	
10) Field work logistics	
11) Provision of services	
12) Other (specify):	
In-kind contributions to indirect costs of research	
4) Use of organization's facilities	
5) Salaries of managerial and administrative staff	
6) Other (specify):	
Total of all in-kind contributions	
Is this new funding (acquired during this reporting period)?	no

Ocean Tracking Network Canada **NSERC**
Appendix A. 2014 OTN Canada Symposium attendees

Aaron Spares
Adam Comeau
Amanda Barkley
Amy Teffer
Andrew Taylor
Annick Drouin
Arthur Bass
Brian Jones (OTN HQ)
Caitlin O'Neill
Charles Krueger (GLATOS)
Christine Penney (OTN Council; VP at Clearwater Seafoods)
Christopher Holbrook (GLATOS)
Claudio Aporta (Dalhousie University)
Colin Buhariwalla
Collin Middleton
Damian Lidgard
Darrin Baker (Baker Blue Ocean)
David Yurkowski
Duncan Bates (OTN HQ)
Edmund Halfyard
Eduardo Martins
Émilie Simard
Franziska Broell
Fred Whoriskey (OTN Executive Director)
Glenn Crossin
Graham Raby
Jacqueline Chapman
Jeannette Bedard
Jeffrey Beardsall
Jessica Ives
Joanna Mills Flemming
Joe Pratt (OTN HQ)
John Kocik (OTN ISAC)
Jonathan Pye (OTN HQ)
Julian Dodson
Katherine Wilson
Katrina Cook
Kes Morton (OTN HQ)
Kim Aarestrupt (OTN ISAC)
Kim Holland (OTN ISAC)
Kim Whoriskey
Kyle McKenzie (OTN HQ)
Kyoko Ohashi
Laura Biannucci
Laura Logan-Chesney
Laurie Baker
Lenore Bajona (OTN HQ)
Leo Muise (DFO; OTN Council)
Lucia Fanning (Dalhousie University)
Marianne Marcoux
Marta Mihoff (OTN HQ)
Martha Crago (VP Research, Dalhousie University)
Martin Castonguay
Mathieu Dever
Matt Drenner
Matthew Litvak
Mélanie Beguer
Melissa Dick
Mike Donaldson
Mike Stokesbury
Montana F. McLean
Natalie Reinhart
Natalie Sopinka
Nathan Furey
Nathan Stewart
Nich Burnett
Nikki Beauchamp (OTN HQ)
Paul Cowley (OTN ISAC)
Paul V. Snelgrove (CHONe)
Rob Harcourt (OTN ISAC)
Rui Zhang
Sara Iverson (OTN Scientific Director)
Silviya Ivanova
Steve Cooke
Steve Ferguson
Steven Kessel
Sue L'Orsa
Taryn Murray (International HQP)
Vanessa Minke-Martin
Vivian Nguyen
Zdenka Willis (OTN ISAC)